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Electricity Demand Patterns on Anholt: A Small Island without Connection to the Main Power Grid

System Analysis Department & Test Station for Windmills

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A small Island without Connection to the Main Power Grid

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Helge Aagaard Madsen, Jørgen Fenhann, Helle Greisen
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Risø National Laboratory, DK-4000 Roskilde, Denmark
March 1988

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Electricity demand patterns on Anholt.
A small island without connection to the main power grid.

Systems Analysis Department & Test Station for Windmills

Helge Aagaard Madsen
Jørgen Fenhann
Helle Greisen
Helle Trøst Nielsen

Abstract. This report contains the results from a study of the electricity demand made at the island of Anholt during 1984 and 1985. During 3 weeks in March 1985 measurements of power and reactive power demand was made with timesteps of 1 second. These data together with existing data for 1984 was analysed in order to examine the variations in the power demand, short time as well as long time variation, which are of great importance in the analysis and design of wind/diesel systems. The Island of Anholt is of special interest because it is without connection to the main Danish grid and because it has been considered to install a wind/diesel system here. The technical data and the operation of the existing power station at Anholt are described in appendix A. Appendix B contains a set of curves showing the daily variations in power demand.

March 1988
Risø National Laboratory, DK-4000 Roskilde, Denmark

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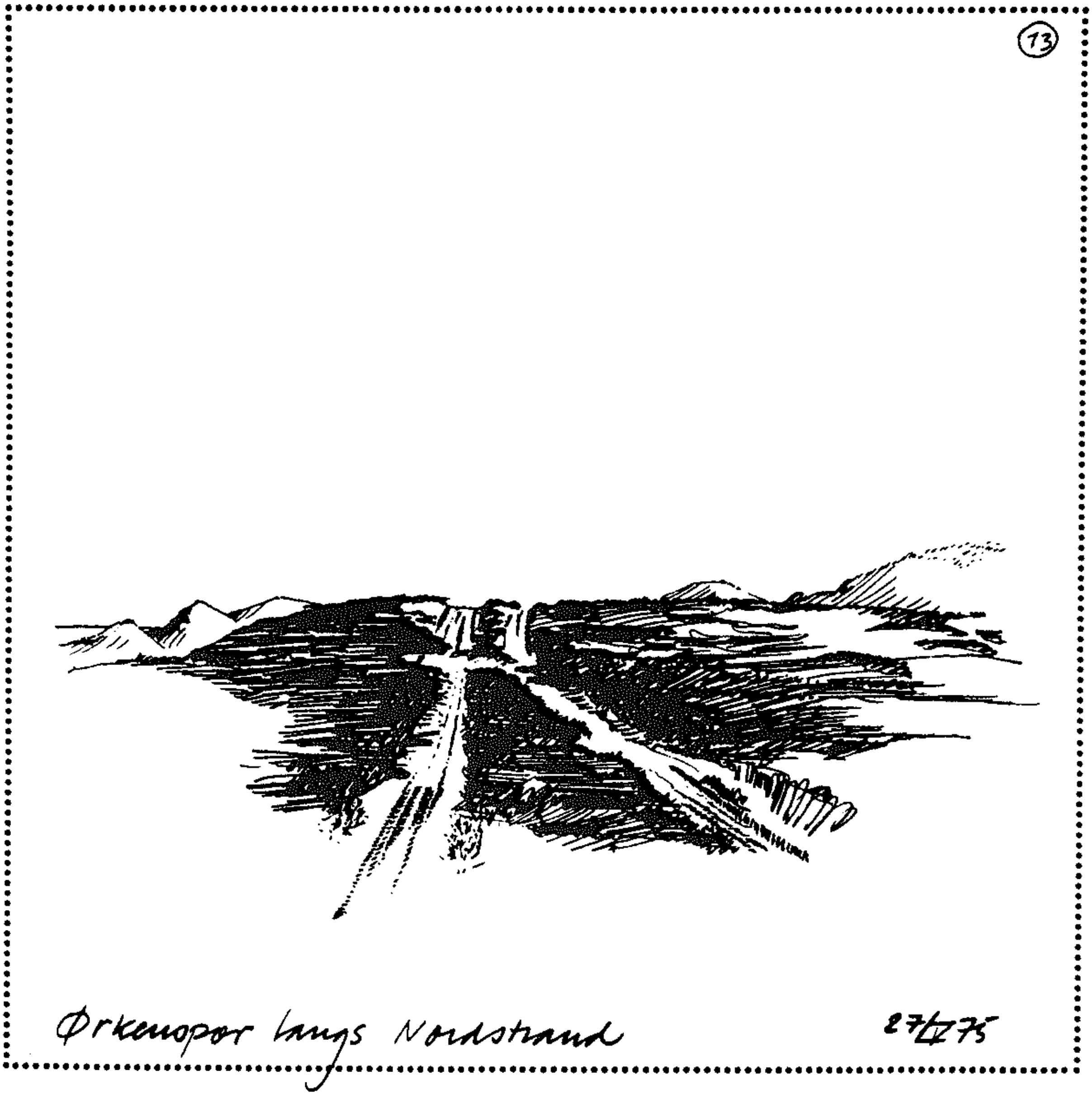
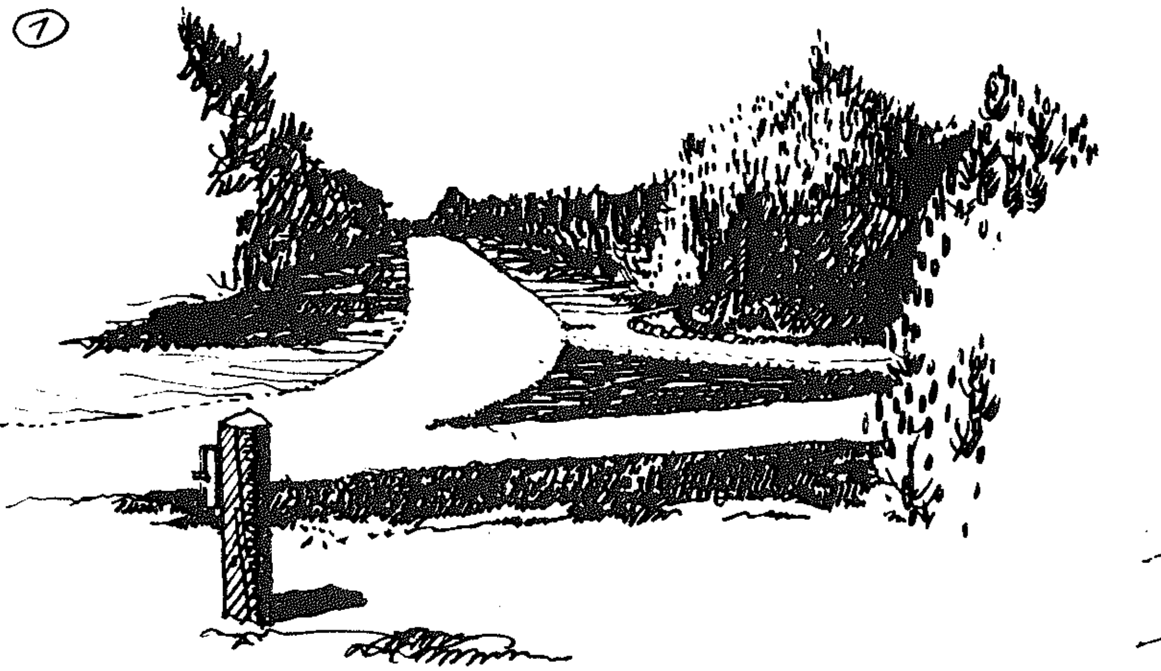


Desert track along Nordstrand

1



Nordstrandvej, ved ankeret, set mod havnen
7/VI 75

Nordstrandvej at the anchor, view towards the harbour

PREFACE

The purpose of this project has been to investigate the electricity demand patterns in a small community without connection to the main power grid. The background is the growing interest in wind/diesel systems.

The work was performed by Helle Trøst Nielsen and Jørgen Fenhann from the Energy Systems Group in the Systems Analysis Department, Helle Greisen and Helge Aagård Madsen from the Test Station for Windmills. Some of the computer programs used were written by Jim Halliday from the Energy Research Group at Rutherford Appleton Laboratory, U.K., who stayed at Risø during the autumn 1984. The drawings from Anholt is from the drawing office of Tormod Olesen.

The island of Anholt

From Anholt town

1. INTRODUCTION

The study is part of the activities within the wind/diesel programme at Risø, which was initiated in 1982. At an early stage within this programme it became clear that data on electricity demand on small grids were sparse but very much needed.

Therefore in 1984 and 1985 measurements of electrical demand were made on the island of Anholt, it is an island with a small community without connection to the main power grid. The electrical supply is generated by 3 diesel generators, one at 135 kW and two at 212 kW.

The aim was to derive the characteristics (long time variations as well as short time fluctuations) of the power demand pattern on a small isolated grid. Such data are of great importance in the design, analysis and simulation of wind/diesel systems.

The village hall

2. ANHOLT

Anholt is situated in Kattegat at 56° latitude 11° longitude about 50 km north-east of the town Grenå in Jutland.

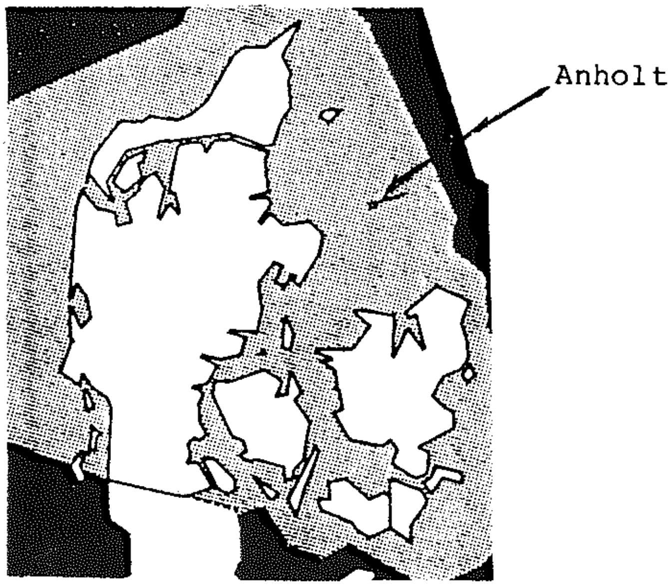


Fig. 2.1. Position of the island Anholt

Anholt is shaped by the wind, which is mostly from southwest.

A big part of Anholt is covered by dunes, a result of deforestation 300 years ago. The desert was at that time covered by a pine forest.

At the westcoast the town of Anholt is situated. Anholt has approximately 160 inhabitants living in Anholt town mostly making their living by fishing and tourism - during summer Anholt attracts a high number of tourists, around 15.000.

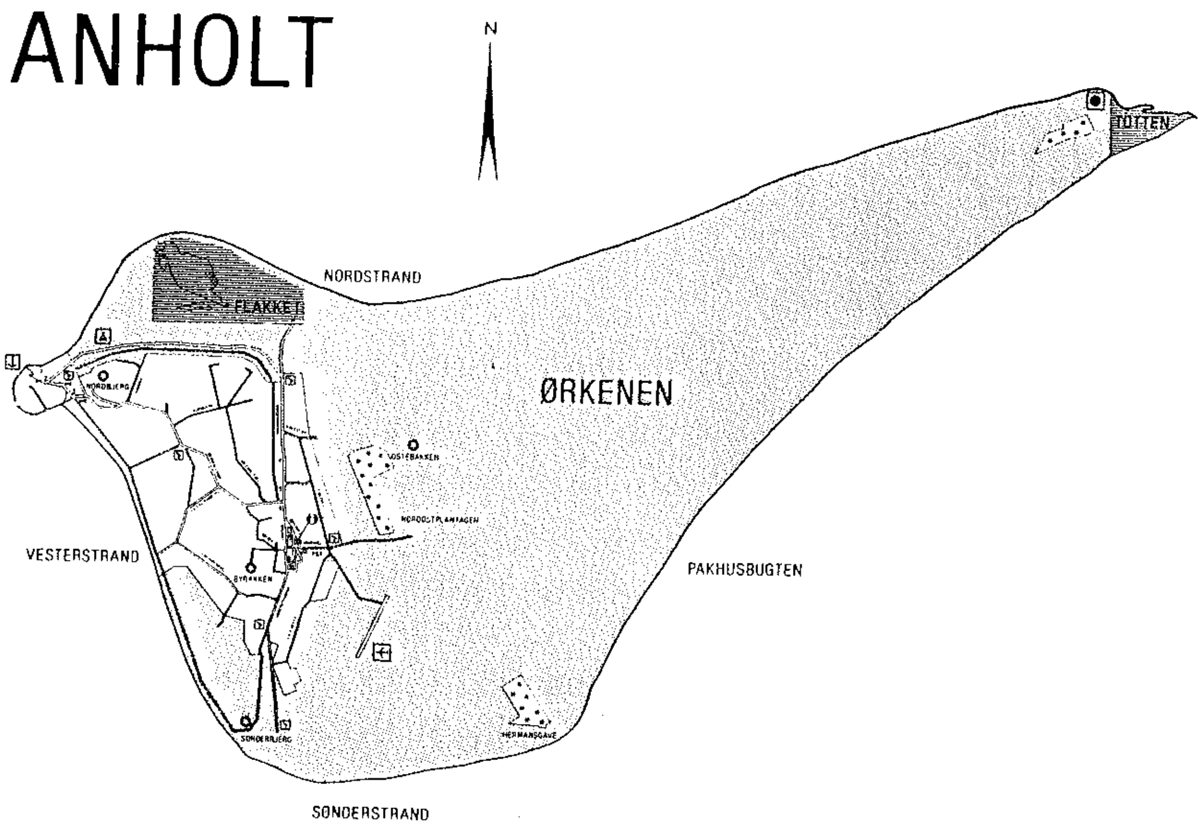


Fig. 2.2. Details of the island Anholt.

The size of the population is relative stable and the division in age cohorts is known from a survey in 1986 (ref. 4).

Age Cohort	Population
0-14 years	36
15-24 "	17
25-64 "	87
65- "	18
Total	158

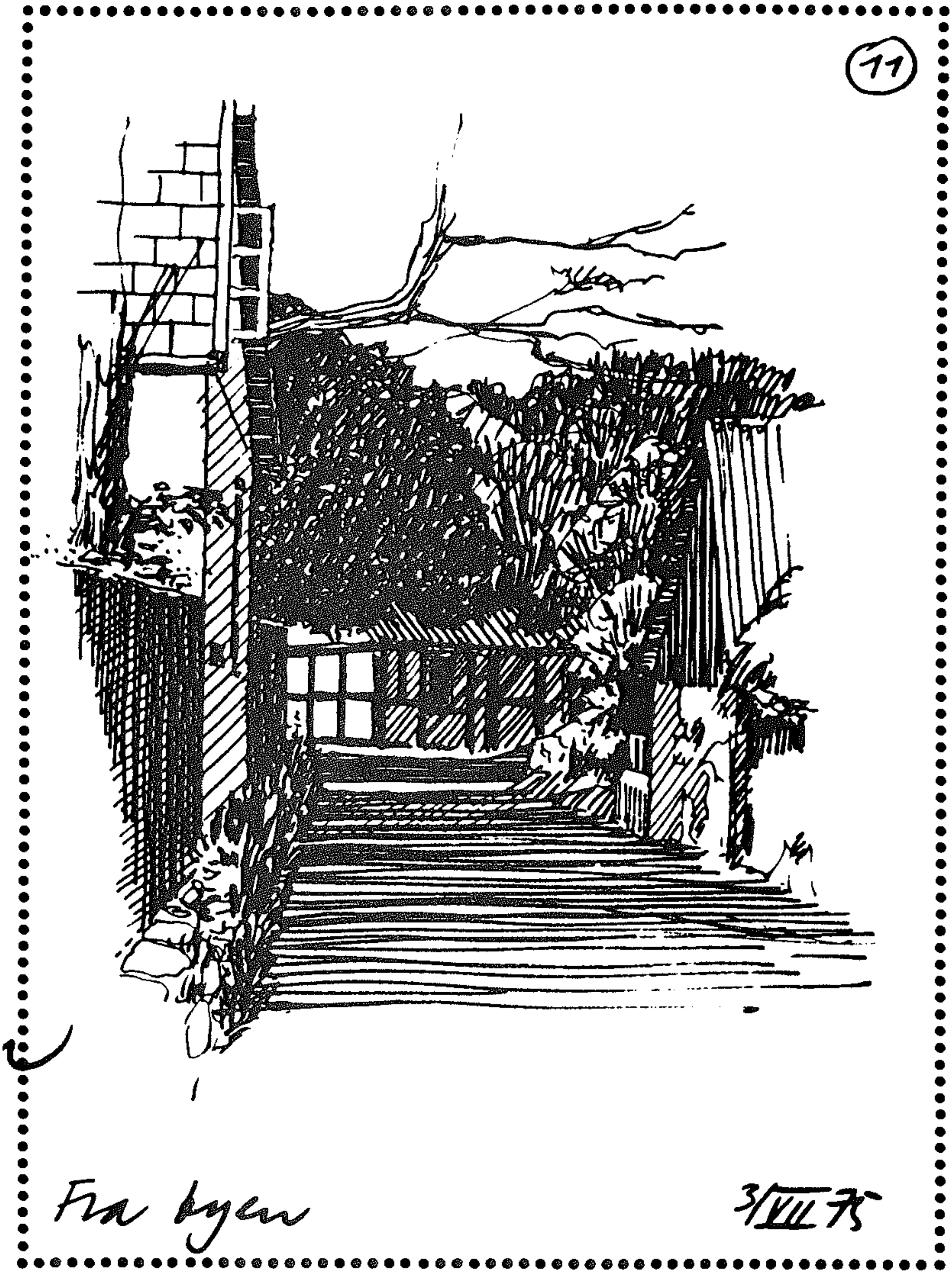
The number of dwellings in 1961 is divided on the following types (ref. 3):

Dwellings in single family houses	60
" in multi family houses	9
Agricultural holdings	3
Summerhouses	108

Since 1961 the number of summerhouses has increased to about 160, while the other numbers are unchanged. Electrical heating is only used in the summerhouses.

There is no industry on Anholt, the largest electricity consumer is a cold-storage plant. There are a number of smaller consumers in the service sector:

12	Shops
3	Inns/pubs
1	School
1	Library
1	Post office
1	Church
1	Carpenter
1	Smith
1	Market garden

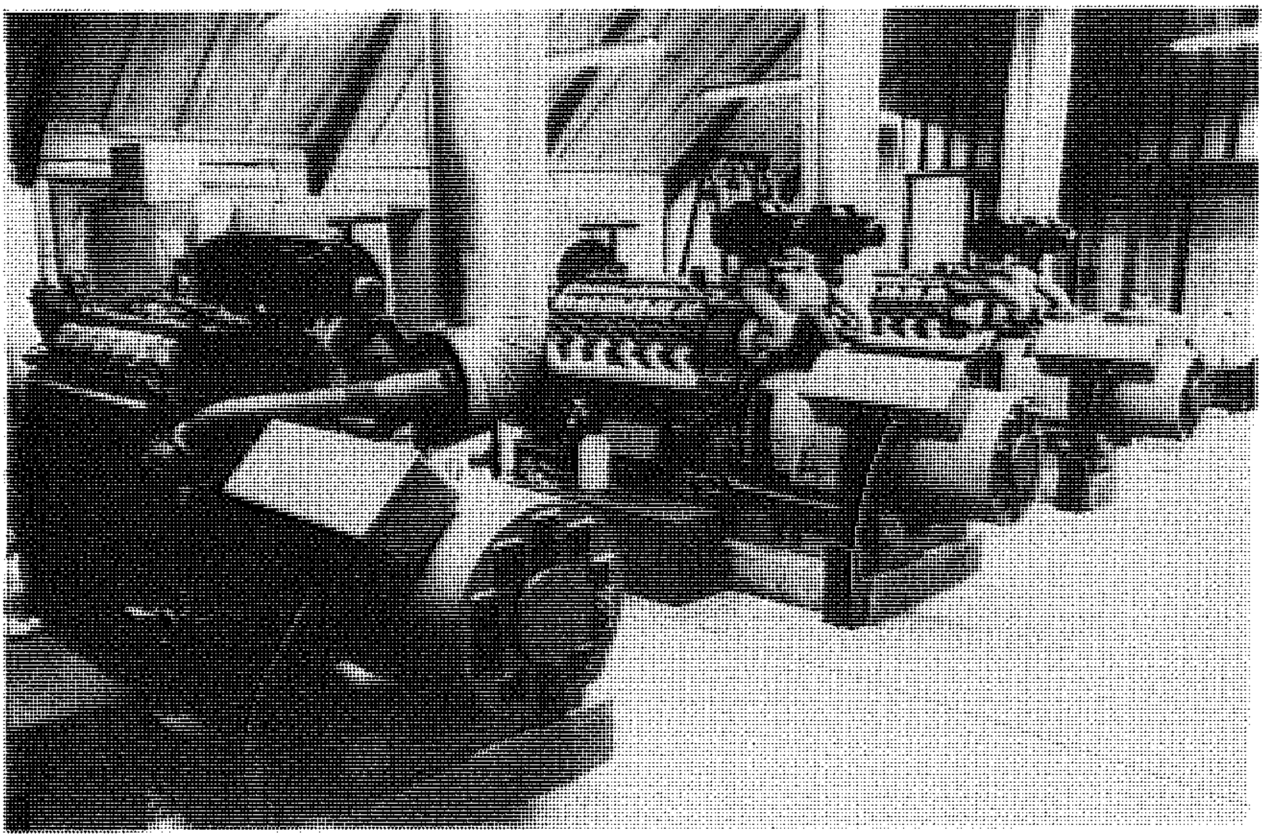


From the town

3. ELECTRICITY SUPPLY ON ANHOLT

The present power station on Anholt was build in 1981. It consists of three 12-cylinder water cooled MWM-dieselmotors (Motoren - Werke - Mannheim), one of 135 kW and two of 212 kW. The two big machines are equipped with turbo charger (described in appendix 1). The small machine is best suited to meet a varying demand. The frequency is held between 49.98 Hz and 50.02 Hz. The noise reduction arrangement is quite effective.

The diesel oil is stored in two tanks each containing 25.000 l of oil. The consumption of one day is kept in the building.



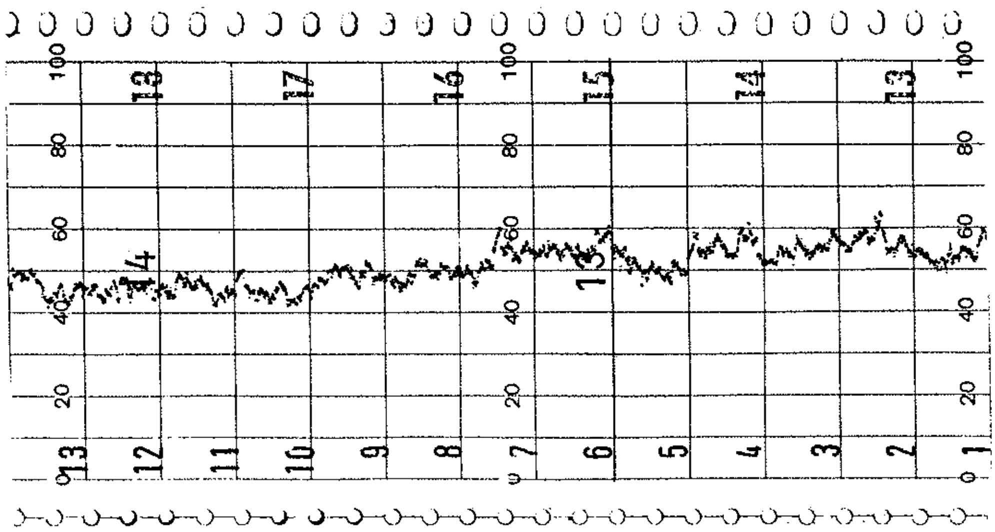
The power station on Anholt

4. MEASUREMENTS OF THE ELECTRICITY DEMAND PATTERN

Two different and independent measurements of the electricity demand pattern have been performed. The first type of measurement is based on a mechanical strip chart recorder and covers the whole year 1984 (36 rolls). The main problems with this kind of recorder are i) someone forgetting to change the chart - this is the reason for most of the gaps in the data ii) misalignment of the pen with respect to the short axis thus e.g. causing a load of 50 kW to be recorded as 75 kW - this did not appear to be a problem in the case of the Anholt data iii) misalignment of the pen with respect to the long axis - thus displacing the time - this was observed to a small extent (the end of 1 roll and the start of the next sometimes overlapped by up to 10 minutes).

A sample of the chart is shown below:

400 kW



0 kW

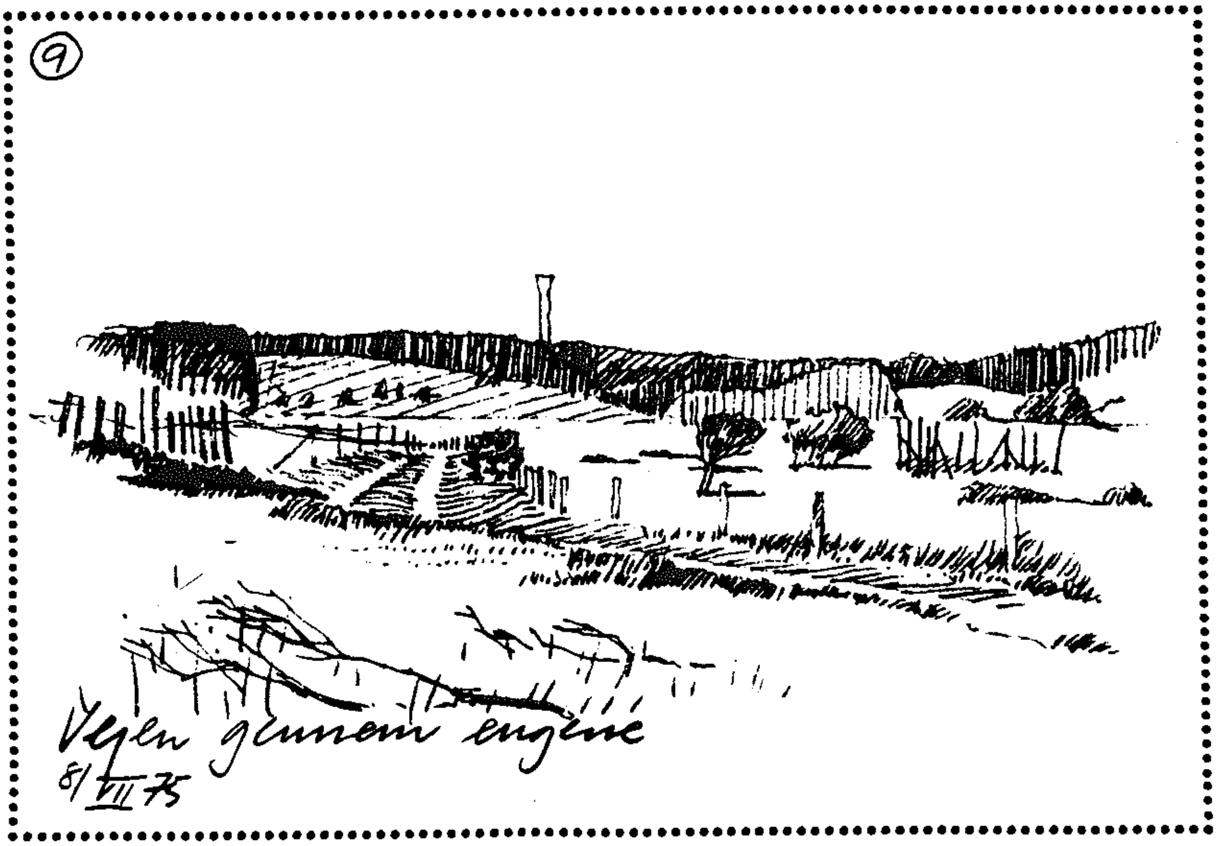
Direction of chart movement

Fig. 4.1. A piece of a chart recorder roll

The short axis is scaled from 0 to 100 (across the 5.5 cm). The full scale deflection would correspond to a load of 400 kW. The long axis is marked by several different sets of numbers - the relevant ones (in our case) are the large numbers in the centre (13 and 14 on the sample shown), these refer to the time of the day in hours, and the smaller dark ones along the bottom of the chart (range 1 to 24), these refer to the number of 10 minutes periods since respectively 24.00, 04.00, 08.00, 12.00, 16.00 or 20.00. It can be seen that sometimes the trace is fairly broad (1 mm ie about 7 kW). The uncertainty on the data is therefore ~ 7 kW.

The data is of high reliability - the gaps are normally a matter of a few hours long. The data for 1984 take up 36 rolls, that is one roll contains about 11/2 week. The data on the rolls were digitised using a digitising board. Data was entered for every 10 minutes in the way that the average value within this period was visually estimated.

The second type of measurement used an automatic PC data aquisition system (HP 3421 A). The measurement period was only about 3 weeks (15/3-1985 to 1/4-1985), but with a high time resolution of 1 second and measurements of both active and reactive power consumption. All the data are stored on the mainframe computer at Risø.



The road through the meadows

The cement road seen from the meadows.

5. ANALYSIS OF MEASUREMENTS

In this chapter the data in the two measuring periods are analysed. In the first period from 1/1-84 to 31/12-84 the power demand was were digitised as 10 minutes averages. In the second period from 15/3-85 to 1/4-85 both the power and reactive power demand was measured every second.

5.1. Data with 10 minutes timestep

Fig. 5.1 to 5.4 show the power demand on 4 typical days during 1984. Fig. 5.5 and 5.6 show the power demand in a week in November and a week in the tourist season. Finally the demand in the year 1984 is shown in fig. 5.7 and 5.8.

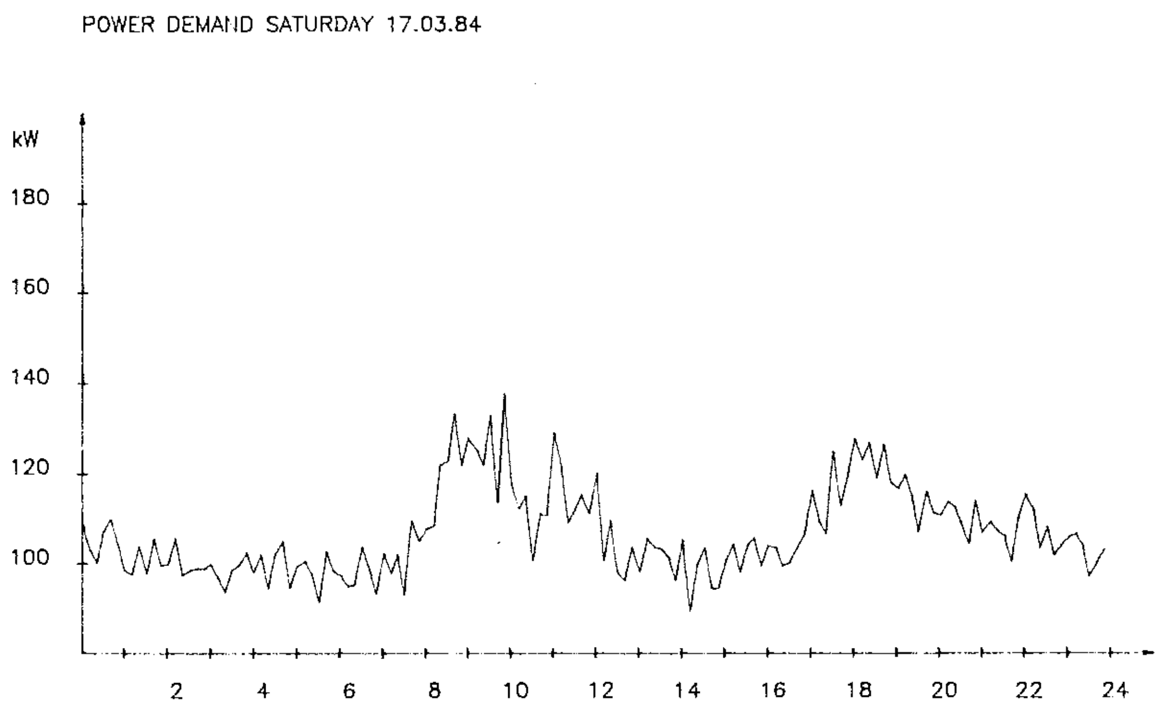


Fig. 5.1. The power demand at a typical day in the spring and with no tourism. There are 2 peaks, one in the morning and one in the evening both presumely caused by cooking.

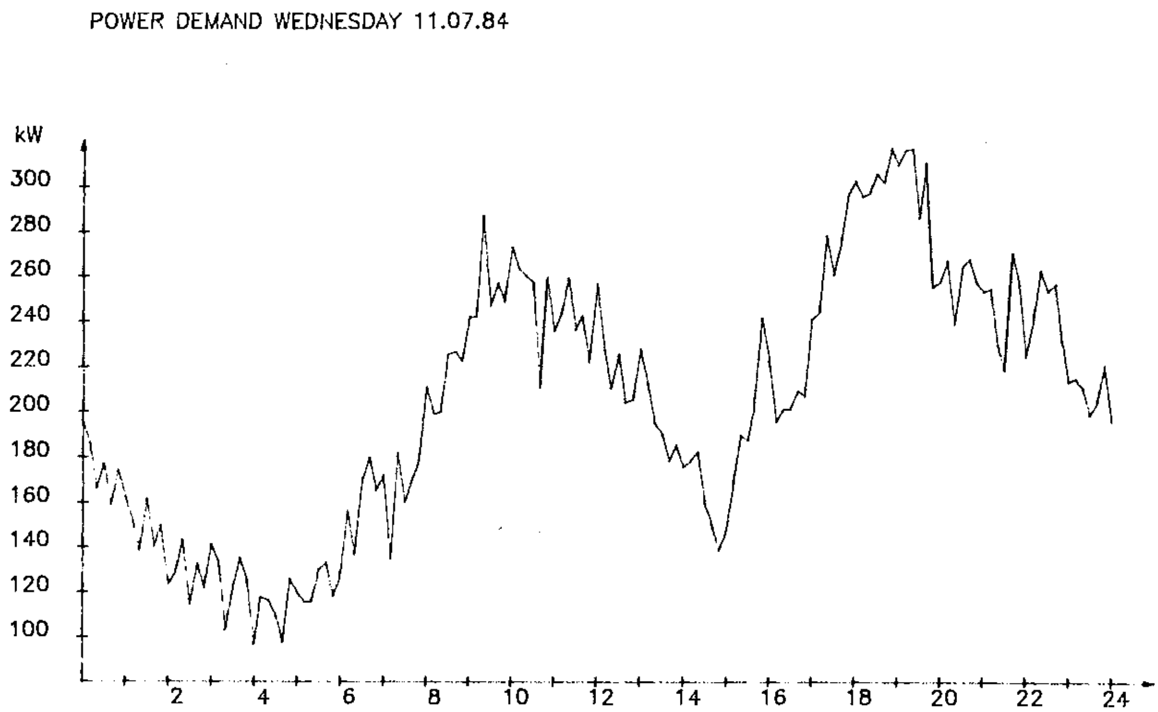


Fig. 5.2. The power demand at a typical summerday with many tourists at the island. The peaks are during the same time at the day as in fig. 5.1, but the variations and the mean value of the power demand are much larger.

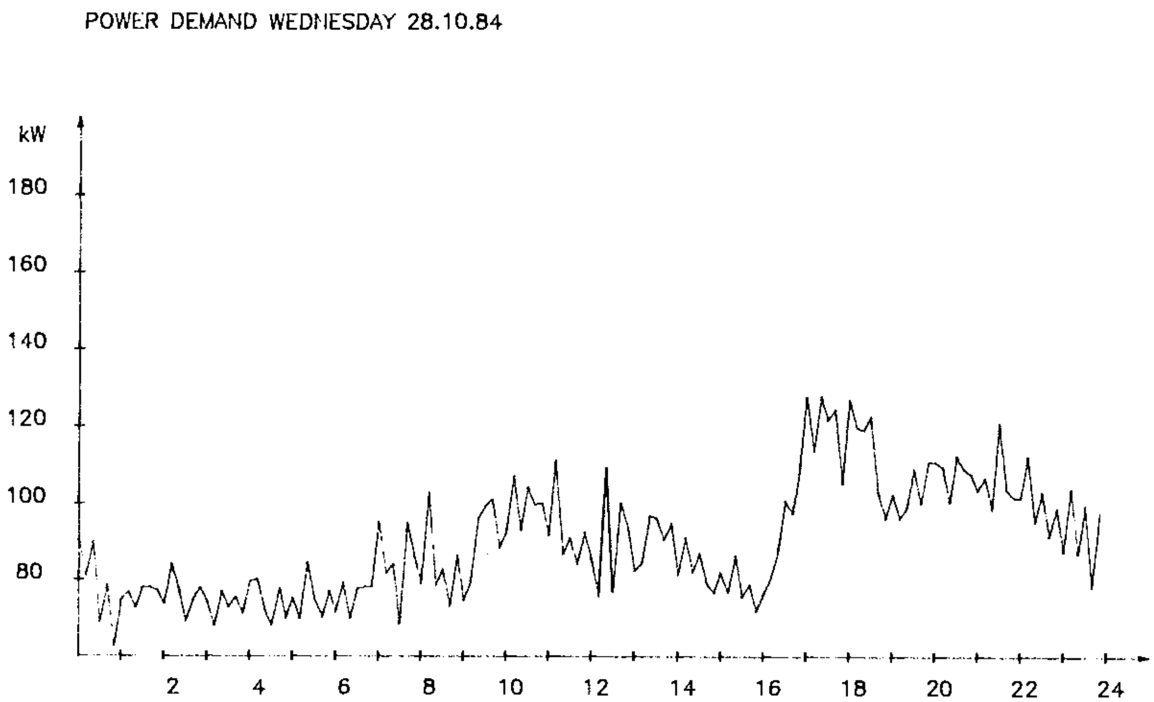


Fig. 5.3. The power demand during a day in October.

Fig. 5.4. The power demand during a day in December. At this winterday there is hardly more than one peak. This is caused by the dinner cooking.

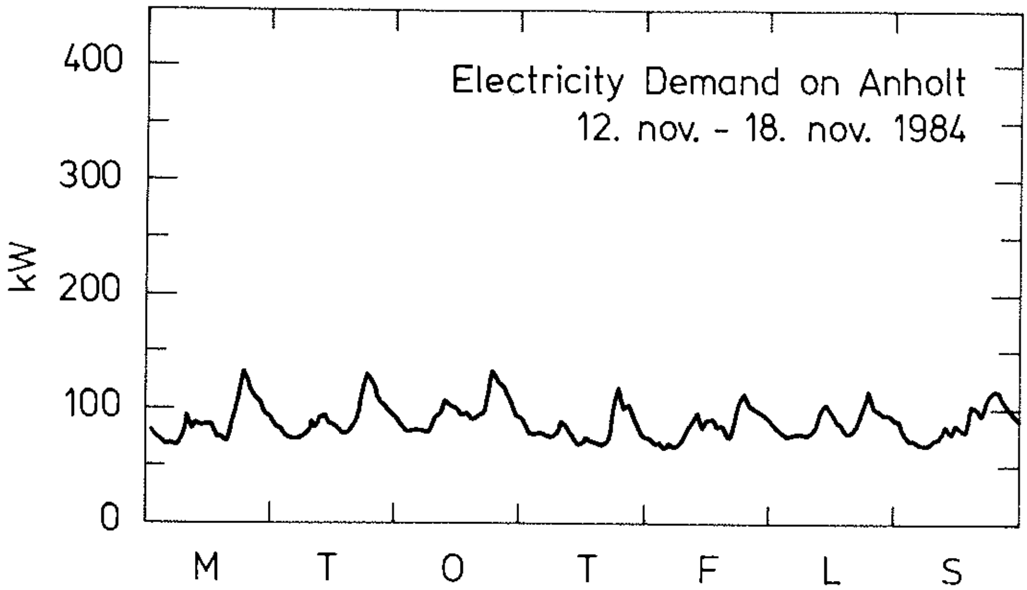


Fig. 5.5. The power demand during one week in November. It is interesting to see that the power smoothes out in the week-end. One reason could be that in the weekend people don't have to cook their meals at a specific time depending on a 8 hours working day.

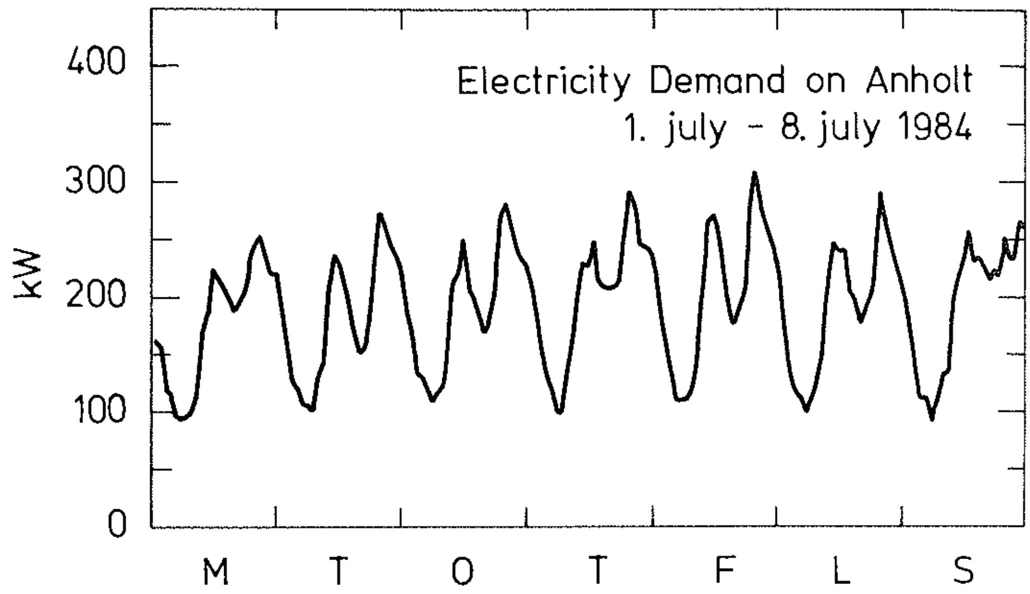


Fig. 5.6. The power demand during one week in the tourist season. A comparison with fig. 5.5 shows that the baseload is only slightly higher in the tourist season whereas the peak-load has increased drastically.

Until 1981 Anholt had an old power station which could not deliver sufficient electricity. In 1981 the new power station described in appendix A was build. Before 1986 the price of a kWh was based on the current operation/working expenses at the power station. In 1986 there was made a decision that all electricity consumers in the municipality of Grenå should pay the same costs for electricity. This fact made the kWh price on Anholt to decrease from about 1,50 Dkr. to 0,75 Dkr. and will presumely cause an increase in the electricity demand over the next few years.

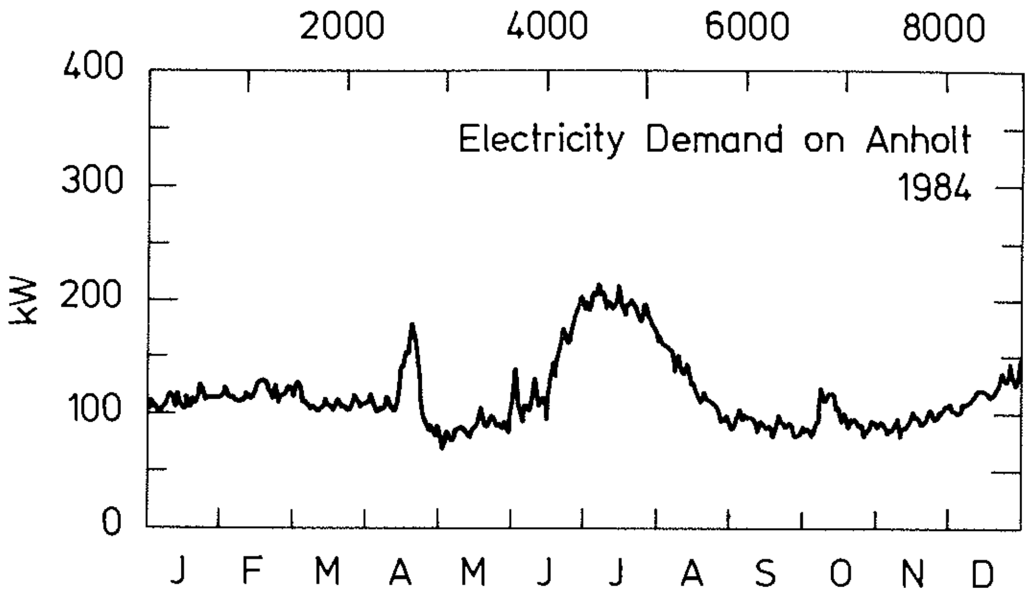


Fig. 5.7. The power demand during 1984. The averaging time is one day. The peaks are in the periods with tourism. The power demand is larger at the end of the year than in the start indicating a rise in the power demand. Additional measurements (ref.5 fig. 3) made at the power station confirms that the demand for electricity has increased by about 10% from 1984 to 1985.

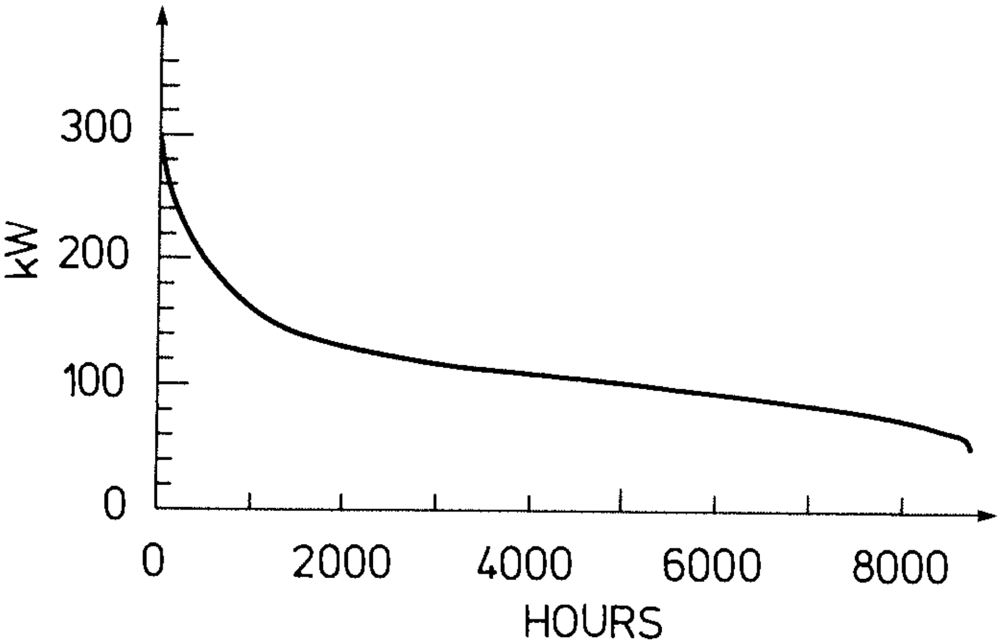


Fig. 5.8. The duration curve from 1984.

5

Nordstrandvejen ved Kroen,
set mod syd 8/VII 75

Nordstrandvej at the inn, view towards south.

	Month	Day	Hour	Min.	Value
Minimum at:	1	5	13	41	70 kW
Maximum at:	1	10	17	11	180 kW
Mean value for month:	1				111 kW
St. dev. - - :	1				17 kW
Total demand - - :	1				82755 KWh
Minimum at:	2	24	8	20	66 kW
Maximum at:	2	17	18	10	178 kW
Mean value for month:	2				117 kW
St. dev. - - :	2				15 kW
Total demand - - :	2				81471 KWh
Minimum at:	3	2	8	20	66 kW
Maximum at:	3	3	19	0	161 kW
Mean value for month:	3				108 kW
St. dev. - - :	3				13 kW
Total demand - - :	3				80903 KWh
Minimum at:	4	30	12	50	55 kW
Maximum at:	4	20	10	30	257 kW
Mean value for month:	4				116 kW
St. dev. - - :	4				32 kW
Total demand - - :	4				83496 KWh
Minimum at:	5	3	5	30	41 kW
Maximum at:	5	31	19	19	167 kW
Mean value for month:	5				86 kW
St. dev. - - :	5				18 kW
Total demand - - :	5				63949 KWh
Minimum at:	6	16	5	1	51 kW
Maximum at:	6	26	17	20	278 kW
Mean value for month:	6				123 kW
St. dev. - - :	6				40 kW
Total demand - - :	6				88855 KWh

Fig. 5.9. (continues on next page)

	Month	Day	Hour	Min.	Value
Minimum at:	7	9	4	38	81 kW
Maximum at:	7	27	18	41	341 kW
Mean value for month:	7				196 kW
St. dev. - - :	7				56 kW
Total demand - - :	7				145575 kWh
Minimum at:	8	30	4	29	48 kW
Maximum at:	8	1	18	20	323 kW
Mean value for month:	8				141 kW
St. dev. - - :	8				42 kW
Total demand - - :	8				104708 kWh
Minimum at:	9	6	4	40	49 kW
Maximum at:	9	26	18	10	163 kW
Mean value for month:	9				91 kW
St. dev. - - :	9				16 kW
Total demand - - :	9				65574 kWh
Minimum at:	10	2	8	22	47 kW
Maximum at:	10	13	18	23	224 kW
Mean value for month:	10				94 kW
St. dev. - - :	10				23 kW
Total demand - - :	10				69819 kWh
Minimum at:	11	16	2	30	59 kW
Maximum at:	11	21	18	21	157 kW
Mean value for month:	11				91 kW
St. dev. - - :	11				16 kW
Total demand - - :	11				65161 kWh
Minimum at:	12	12	13	40	68 kW
Maximum at:	12	31	17	41	207 kW
Mean value for month:	12				114 kW
St. dev. - - :	12				22 kW
Total demand - - :	12				84609 kWh
Total demand for electricity in 1984:					1016876 kWh

Fig. 5.9. For each month in 1984 the value and the time of occurrence for the minimum and maximum power demand are shown. The monthly mean values, the standard deviation and the total demand for electricity is also listed. The values are based on 10-minutes averages.

5.2. Data with 1 second timestep

During 3 weeks in March 1985 (15/3 - 1/4) measurements of power and reactive power demand was made with timesteps of 1 second in order to investigate the size of the fluctuations in the power demand.

Three curves are shown in this chapter, all for the same day in March 1985. In fig. 5.10 the power demand, in fig. 5.11 the power demand relative the mean and in fig. 5.12 the reactive power demand is shown. Such curves for other dates within the 3 weeks period are shown in appendix B.

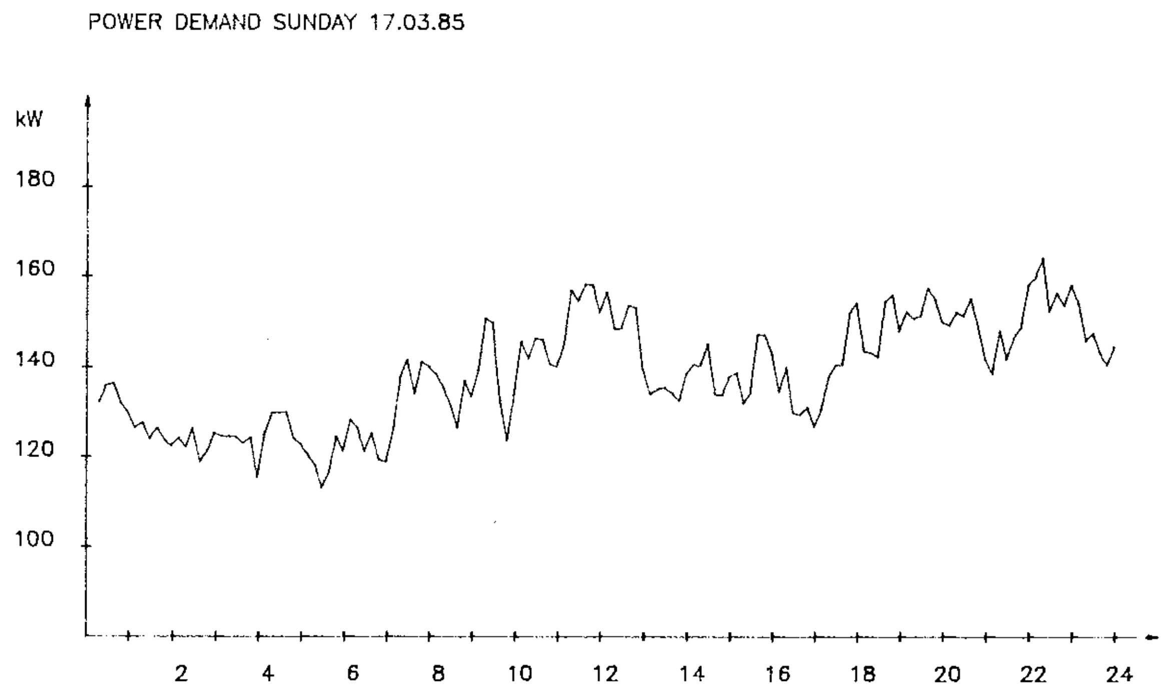
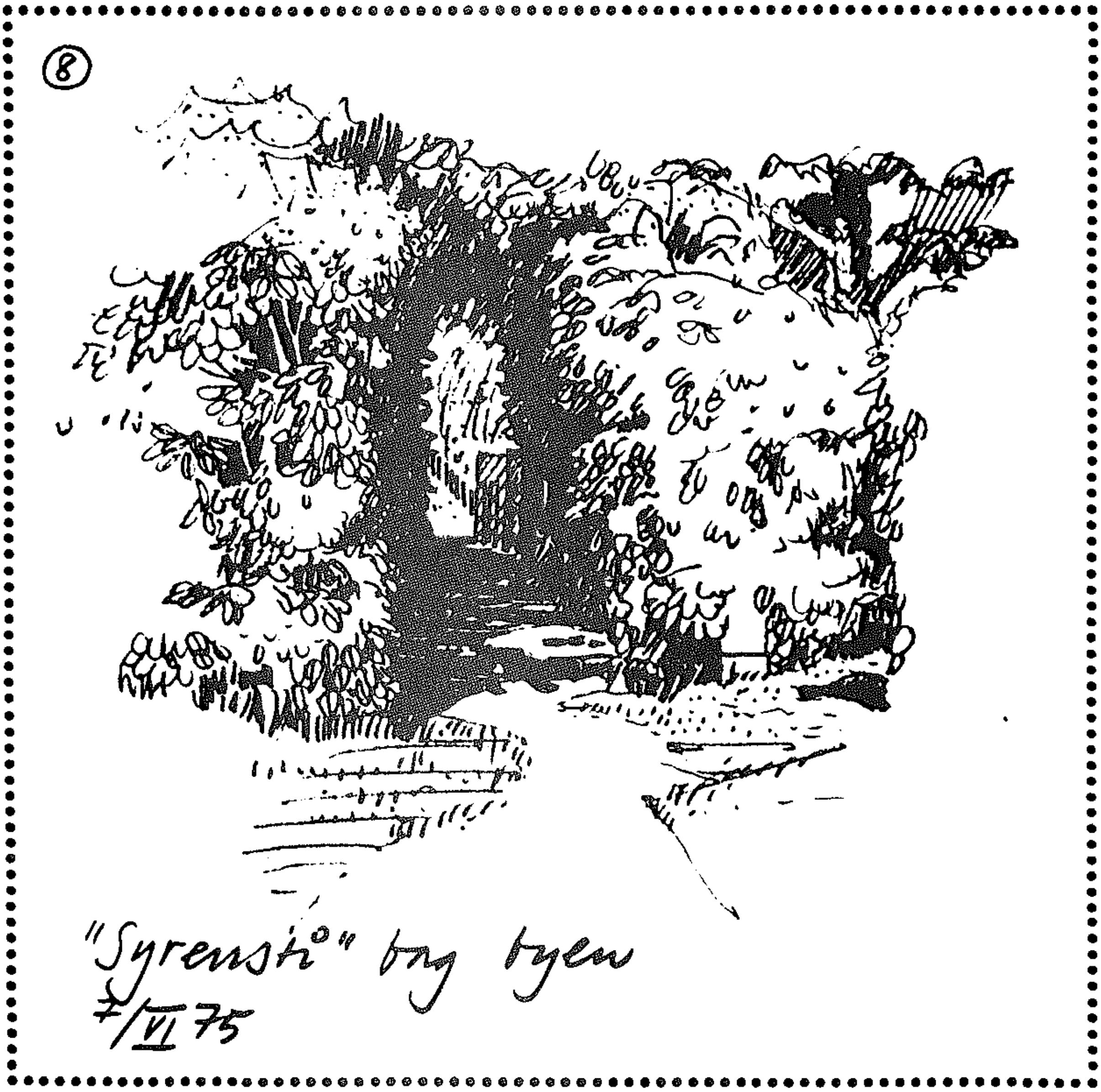


Fig. 5.10. The power demand as a function of time on the 17. March 1985. The averaging period is 10 minutes. The mean value has increased to about 135 kW the 17. March 1985 from 115 kW the 17. March 1984. (See fig. 5.1).



Lilac path behind the town

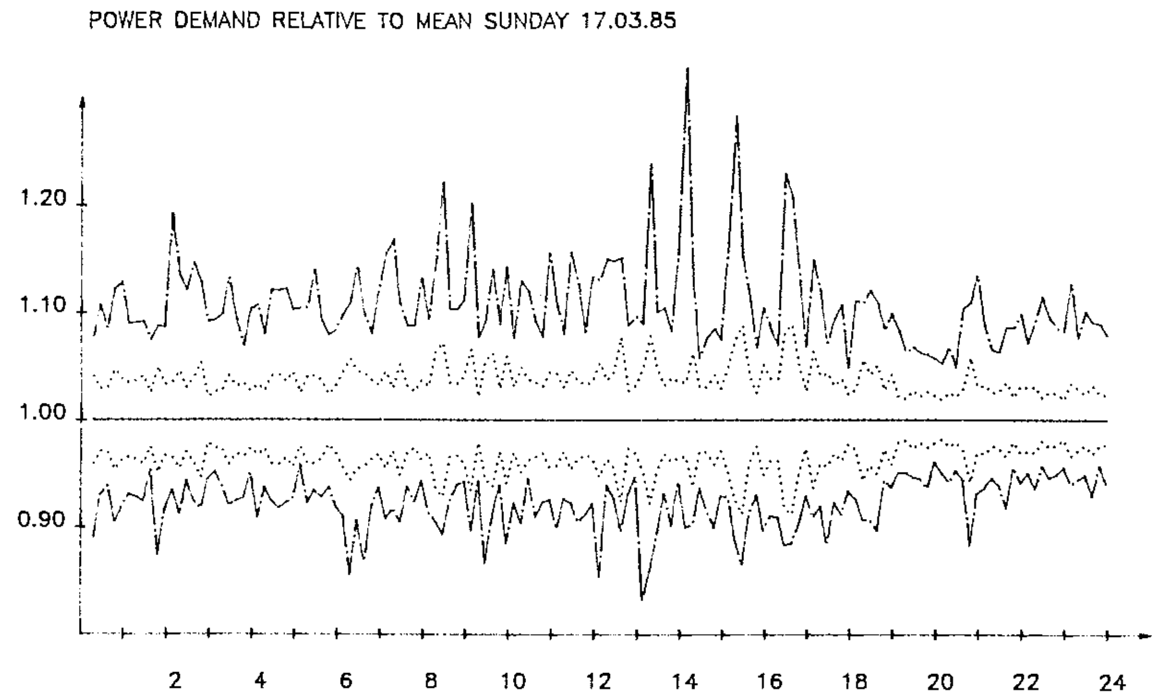


Fig. 5.11. The power demand relative to mean as a function of time during the 17.March 1985. The figure is based on a averaging time of 10 minutes. It shows the standard deviation, the maximum and mean values relative to the mean value.

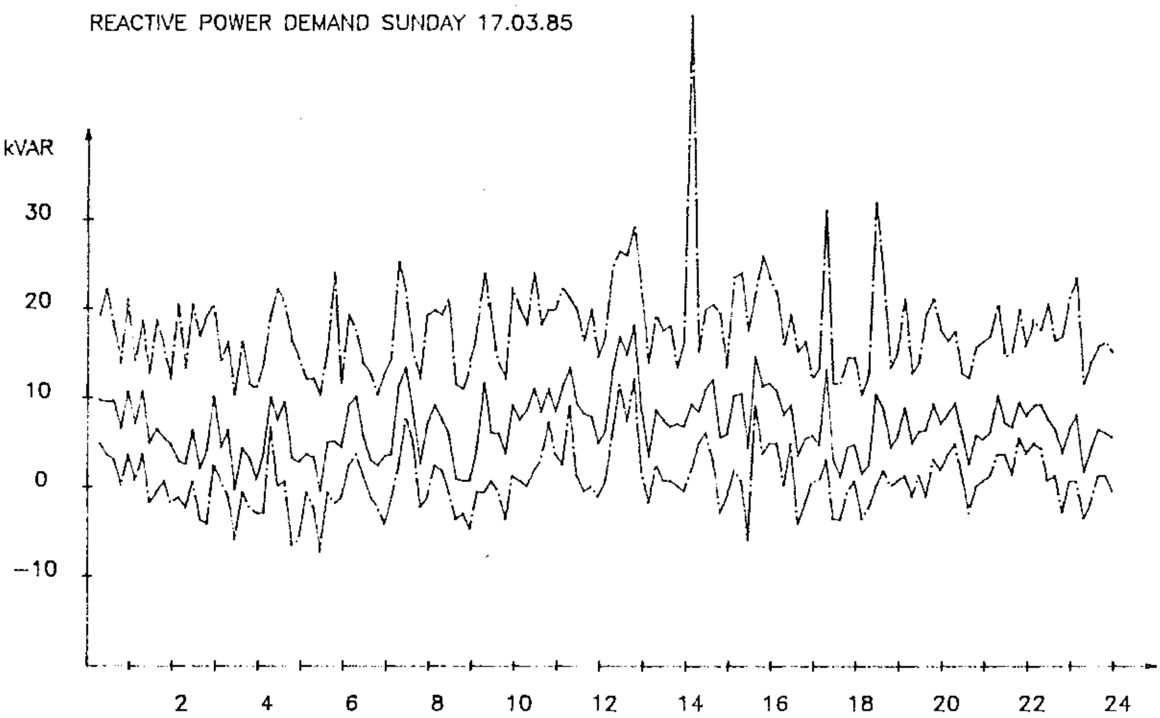
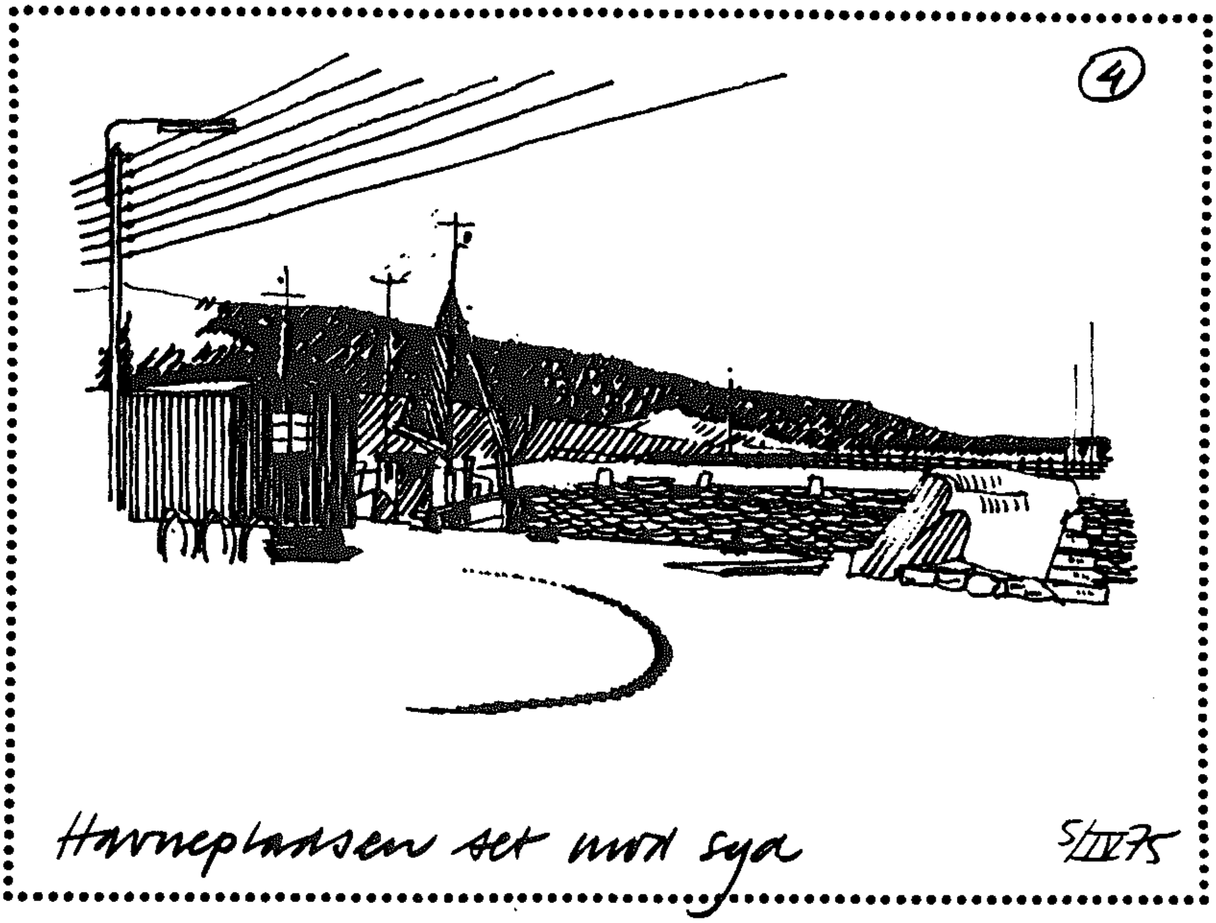


Fig. 5.12. The reactive power demand as a function of time. The averaging time is 10 minutes. Minimum and maximum values are also plotted in the figure.



The harbour, view towards south

6. CONCLUSION

The power and reactive power demand was measured during 3 weeks in March 1985 with timesteps of 1 second. The power demand for the whole year 1984 where digitised every 10 minutes from rolls from a mechanical strip chart recorder.

The data shows some clear peaks for the power demand in the periods with tourism. The power demand doubles in the summer and at Easter. Power demand curves for one week show a regular daily variation. The baseload is only slightly higher in the tourist season whereas the peakload increases drastically (from 100 kW to 300 kW).

The 1985-data contain much information of use for wind/diesel system performance analysis, and they will be used in future work in Risoe's wind/diesel programme.

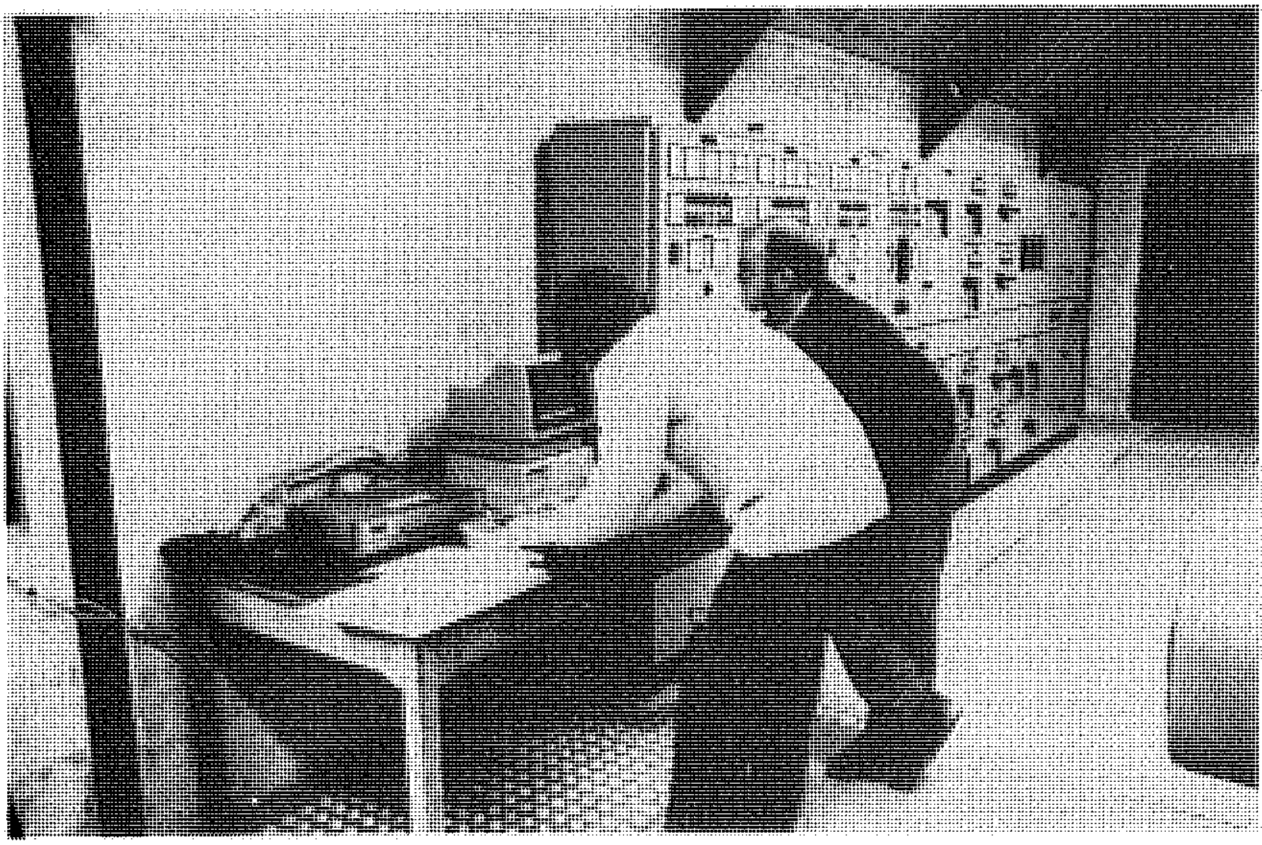
3

Nordstrand klit, vejen mellem
Hammer og Brenaa 2/VI 75

The road between Hammer and Brenaa

REFERENCES

1. SCHOU, Manfred, dec. 1981, Kraftcentralen på Anholt er et lille, teknisk mesterværk. (El & Energi).
2. AALBORG UNIVERSITETSCENTER, juni 1984, Elforsyning ved samdrift af vindmølle og dieselkraftværk.
3. PRINTOUT from the Danish Building Stock Register (BBR), juli 1981.
4. PLANSTYRELSEN, marts 1986, Spørgeskema vedrørende befolknings- og erhvervsforhold på de små øer.
5. ELSAM, projektdivisionen, juni 1986, Forundersøgelse af vind/diesel system.
6. LUNDSAGER, P., MADSEN, H. The Wind/Diesel Development Programme at Risø National Lab. Risø-M-2528.
7. LUNDSAGER, P., MADSEN, H. Modelling and Dynamic Analysis of the Risø Wind/Diesel System. Risø-M-2530.
8. LUNDSAGER, P., MADSEN, H. The Wind/Diesel Test Facility at Risø National Lab. Risø-M-2534.
9. LUNDSAGER, P., MADSEN, H. The Wind/Diesel Development Programme at Risø National Laboratory. Status 85. Risø-M-2537.
10. MADSEN, H., GREISEN, H. (June 1987). Results from the Experimental Wind/Diesel System at Risø. Risø-M-2567.



Installation of the data aquisition system at Anholt

APPENDIX A

Technical data for the power station on Anholt.

One MWM-diesel motor 135 kW
12 cylinders
length of stroke 130 mm
bore 120 mm

Two MWM-diesel motors 212 kW
12 cylinders
lenght of stroke 130 mm
bore 120 mm
turbo charger

Generators:

One AEG Generator Type: DKBH 4284/04, 175 kVA, cos ϕ = 0.8, n = 1500 pm

Two AEG Generators Type: DKBH 4287/04, 265 kVA, cos ϕ = 0.8 n = 1500 pm.

They are all three brushless 3-phase synchronous generators
Frequency: 50 Hz
Voltage : 400 V +/- 0.5% up to full load and with a cos ϕ = 0.8-1.

Operation strategy:

1. First machine (160 kVA) is started manually. When this machine has run at 80% of its maximum load for more than two minutes, the next machine will start, synchronize automatically and take over the load. The first machine will then stop.

2. If the second machine has run at 80% of its maximum load for more than two minutes, the third one will start, synchronize automatically and take over a part of the load.

3. If the second and the third machine have run at 80% of their total maximum load for more than two minutes the first machine will start, synchronize automatically and take over a part of the load.

4. If the three running machines run at less than 70% of the maximum load of two of the machines the last one will stop.

5. If the two running machines run at less than 70% of the maximum load of one of the machines the other one will stop.

6. If the second machine run at less than 70% of the first machine, the first machine will start and synchronize automatically. The second machine will then stop.

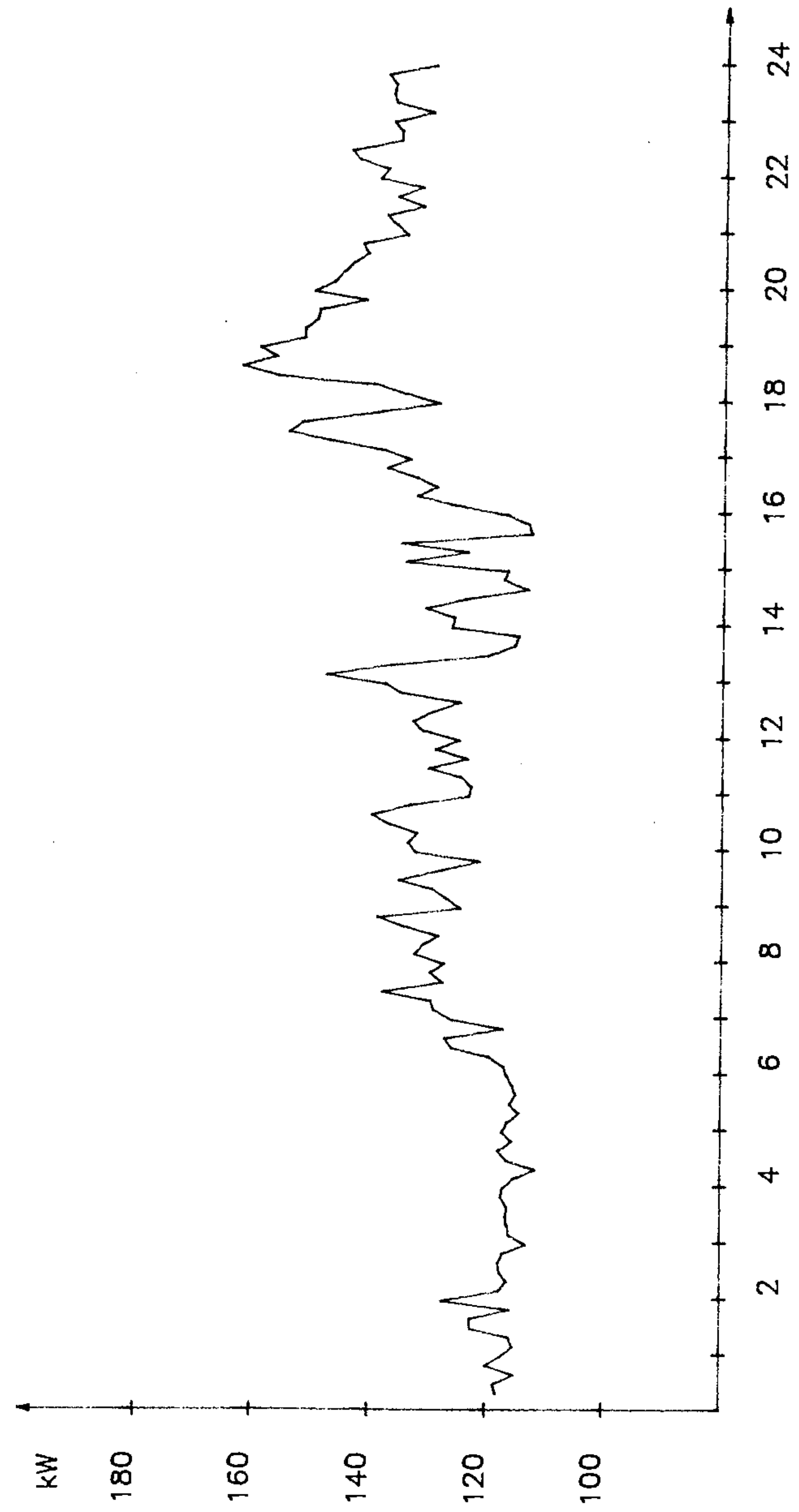
APPENDIX B

A set of curves showing the daily variations in power demand

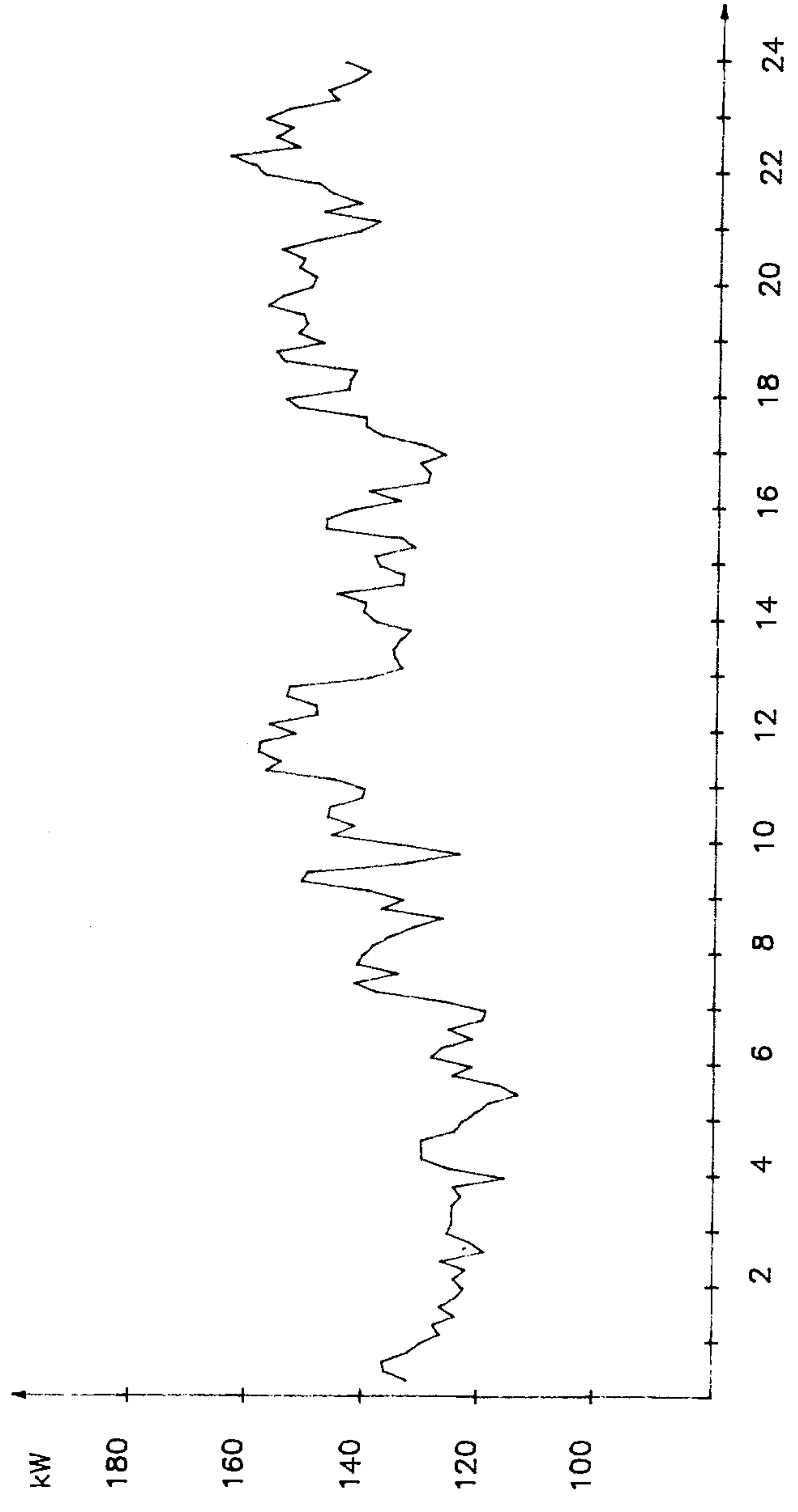
The following curves are based on the 1 second measurements in the period 15/3-1985 to 1/4-1985. The measurement were complete without gaps in 9 days. The daily variations in the power demand are shown for these days in the following. Then follows 4 curves similar to fig. 5.11. for the max. and min. power demand + st.dev. relative to the mean. Finally curves corresponding to fig. 5.12. (the reactive power + min. and max.) are shown. Curves are shown for the days marked with a *.

		Power demand	Power demand relative to mean	Reactive power demand
Saturday	16/3	*		
Sunday	17/3	*	*	*
			*	*
Thursday	21/3	*	*	
Friday	22/3	*	*	
Monday	25/3	*		
Tuesday	26/3	*		
Wednesday	27/3	*		
Thursday	28/3	*		
Sunday	31/3	*		

POWER DEMAND SATURDAY 16.03.85

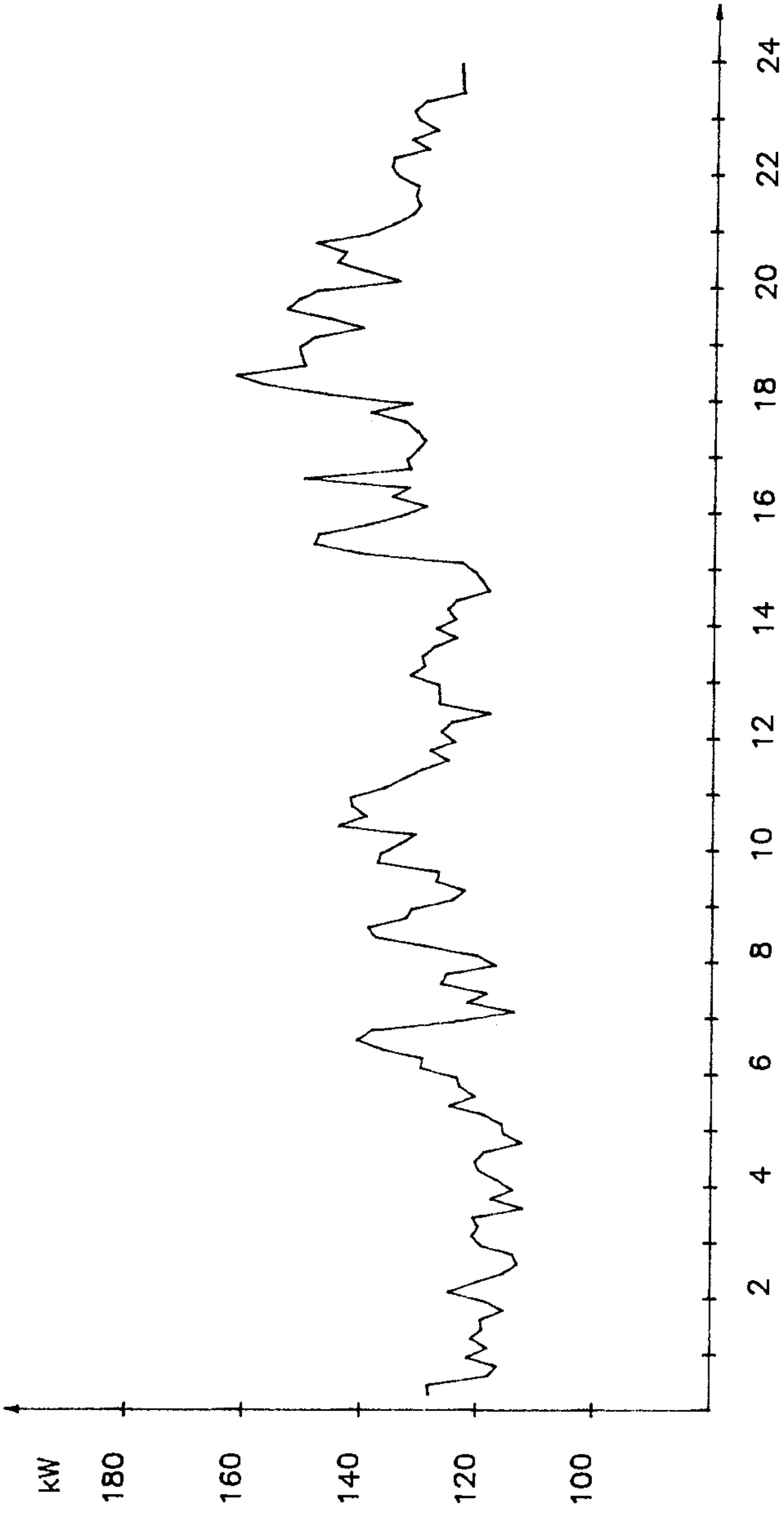


POWER DEMAND SUNDAY 17.03.85

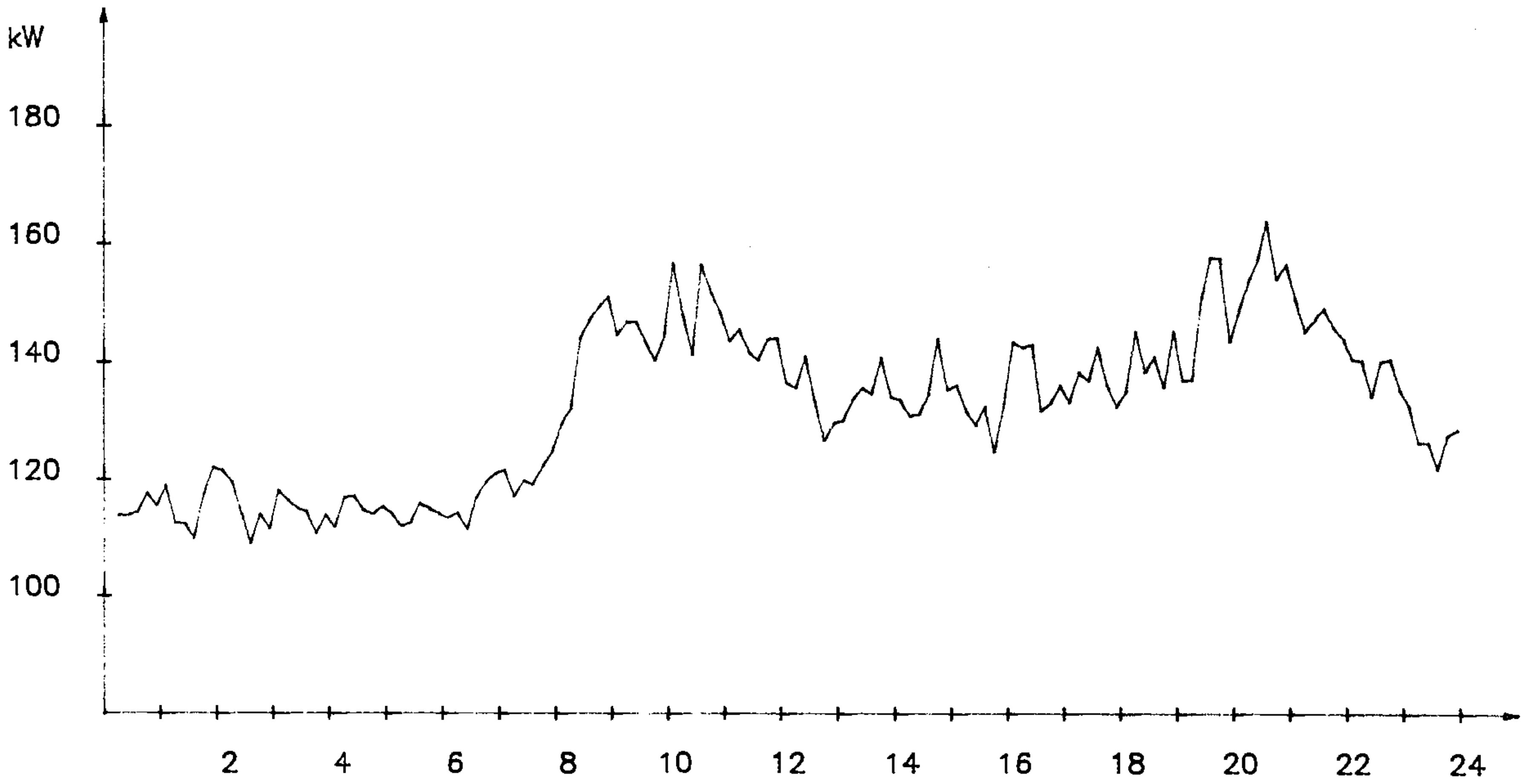


POWER DEMAND THURSDAY 21.03.85

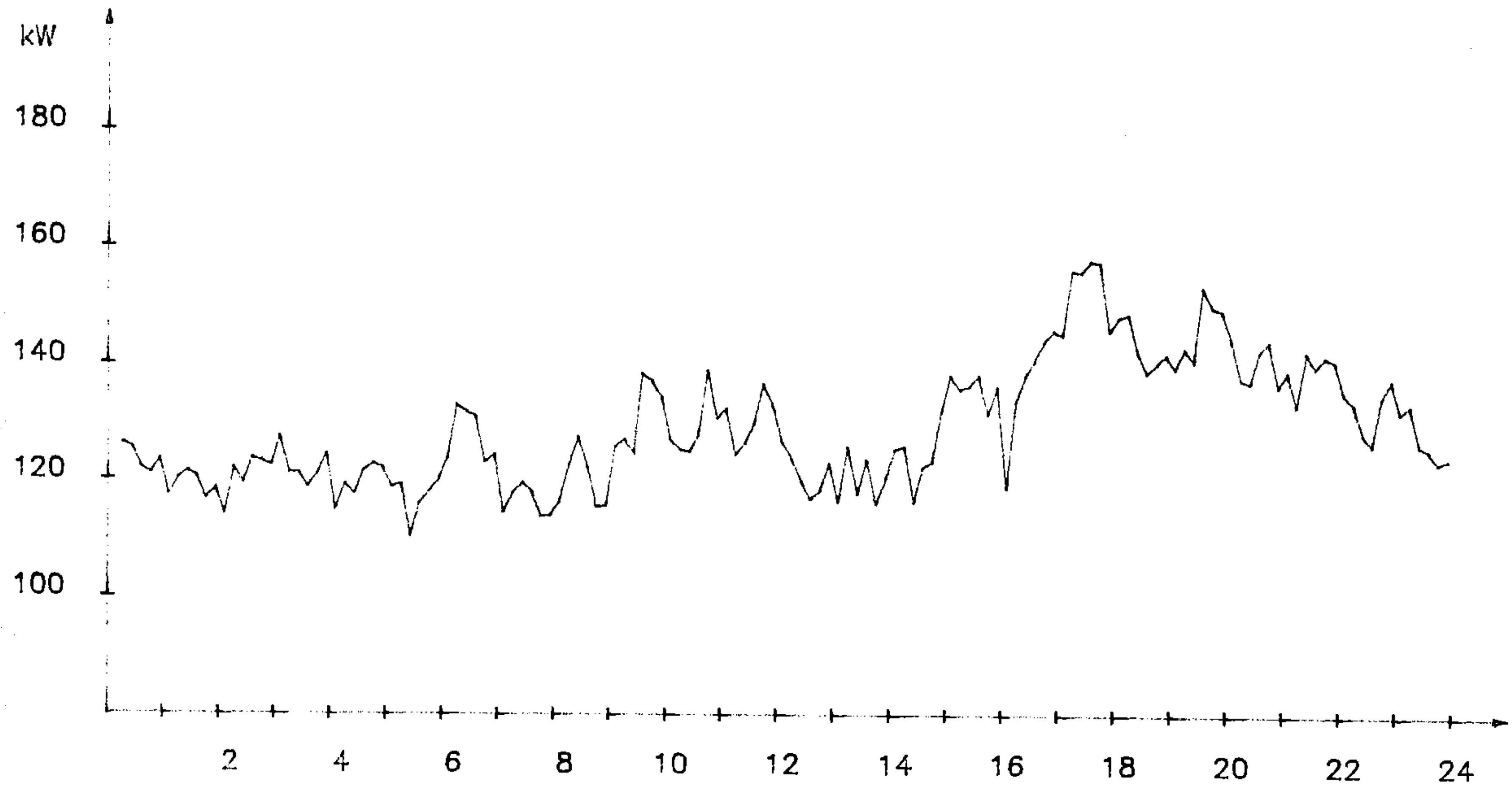
POWER DEMAND FRIDAY 22.03.85



POWER DEMAND MONDAY 25.03.85

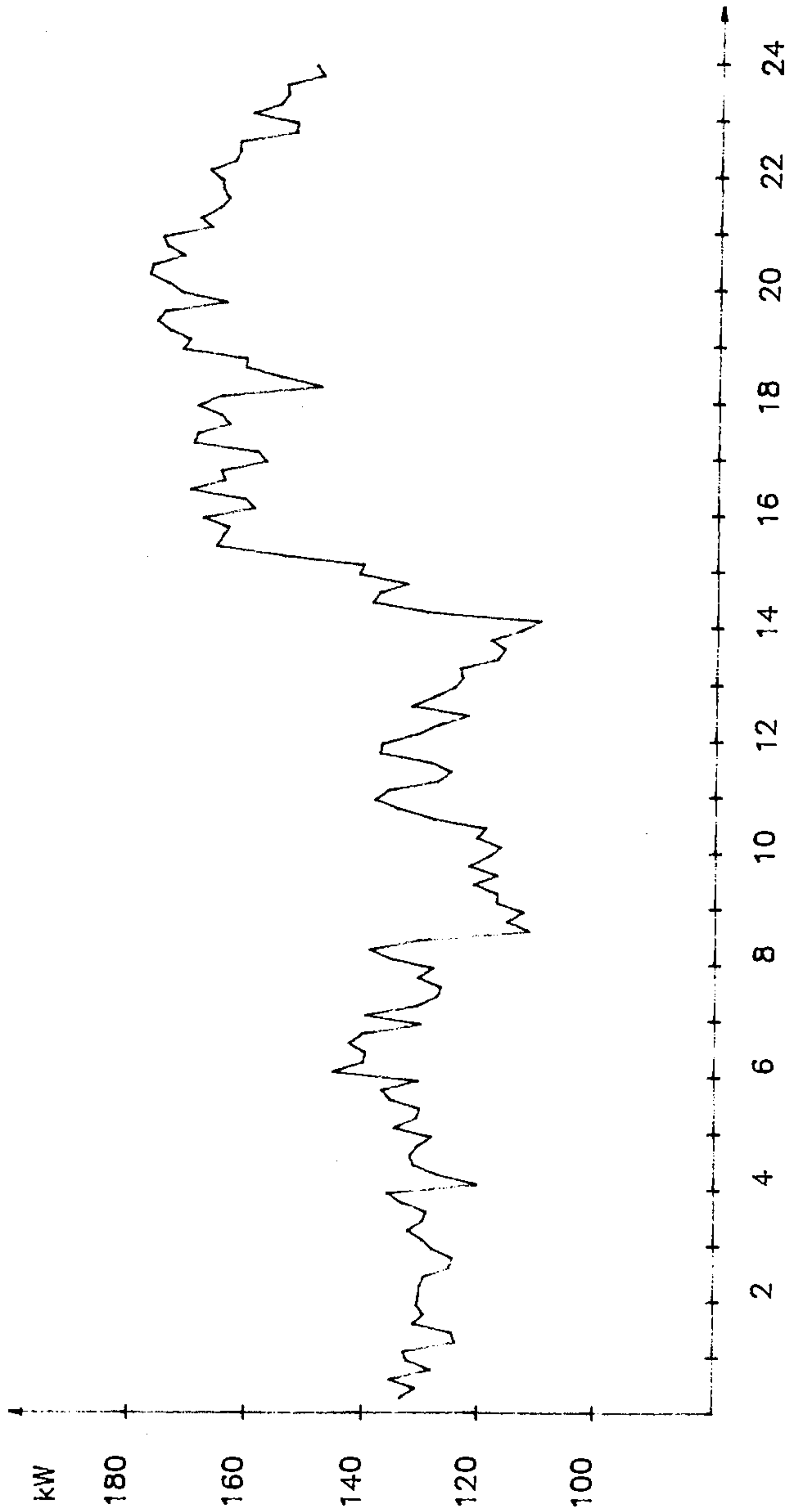


POWER DEMAND TUESDAY 26.03.85

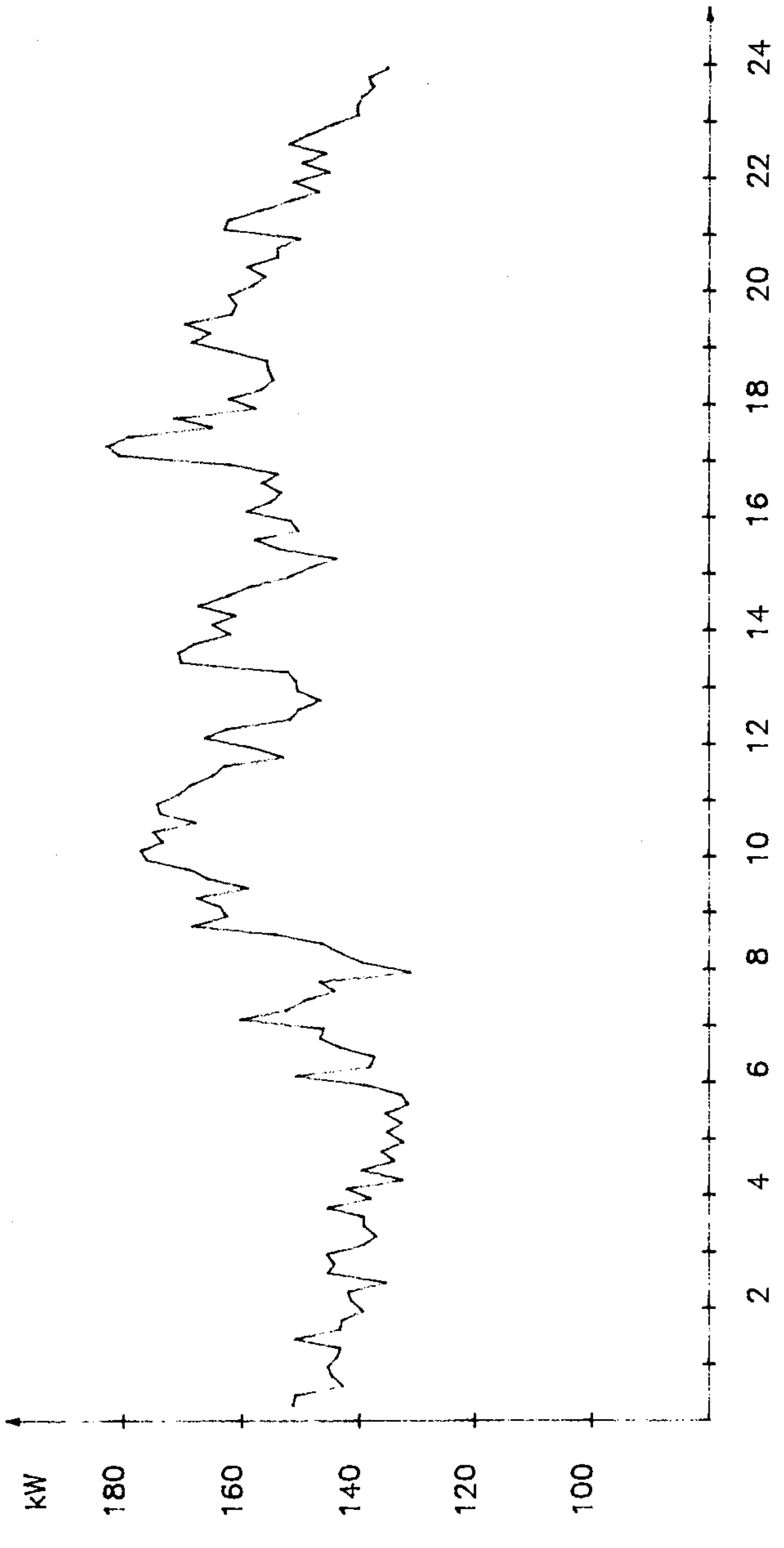


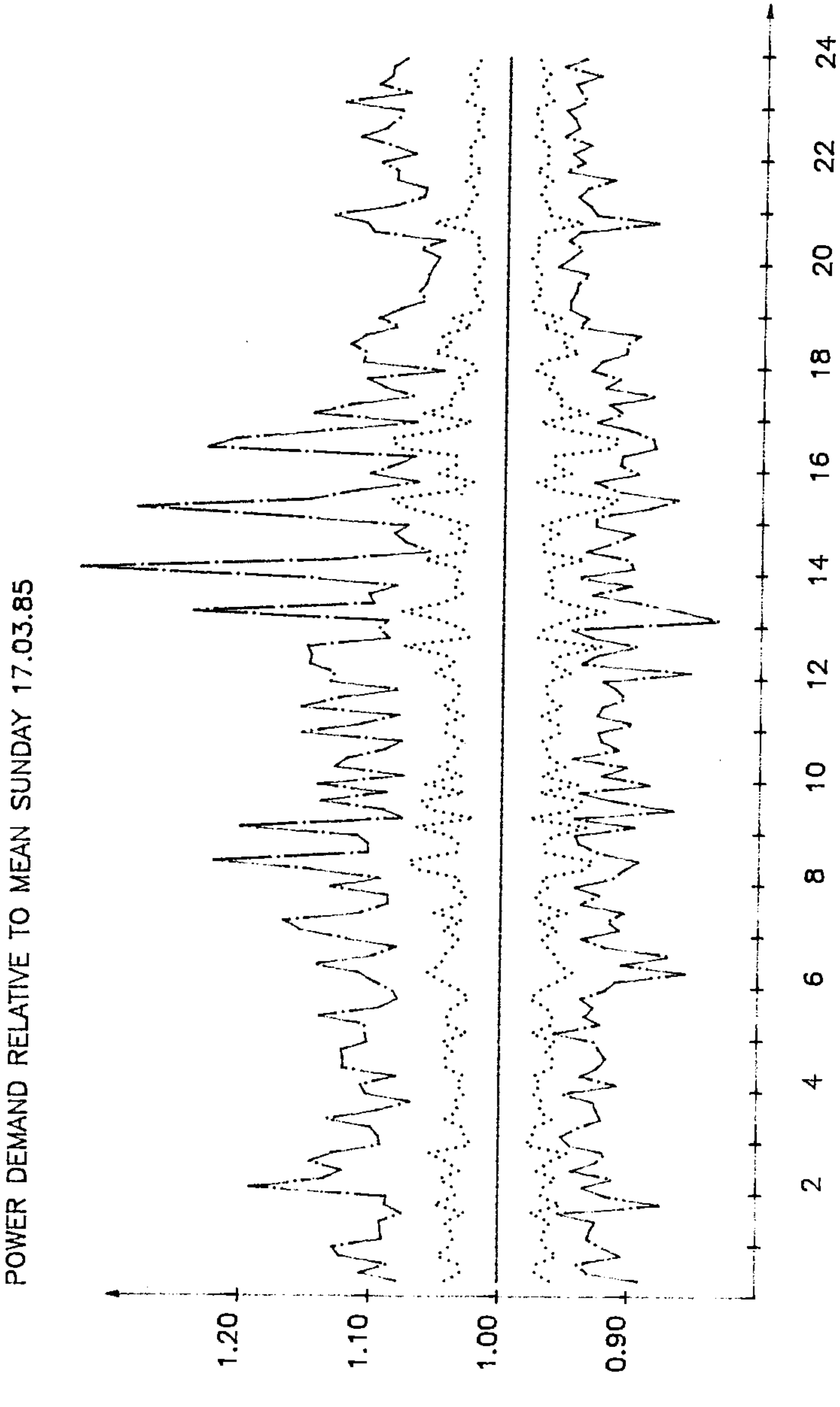
POWER DEMAND WEDNESDAY 27.03.85

POWER DEMAND THURSDAY 28.03.85

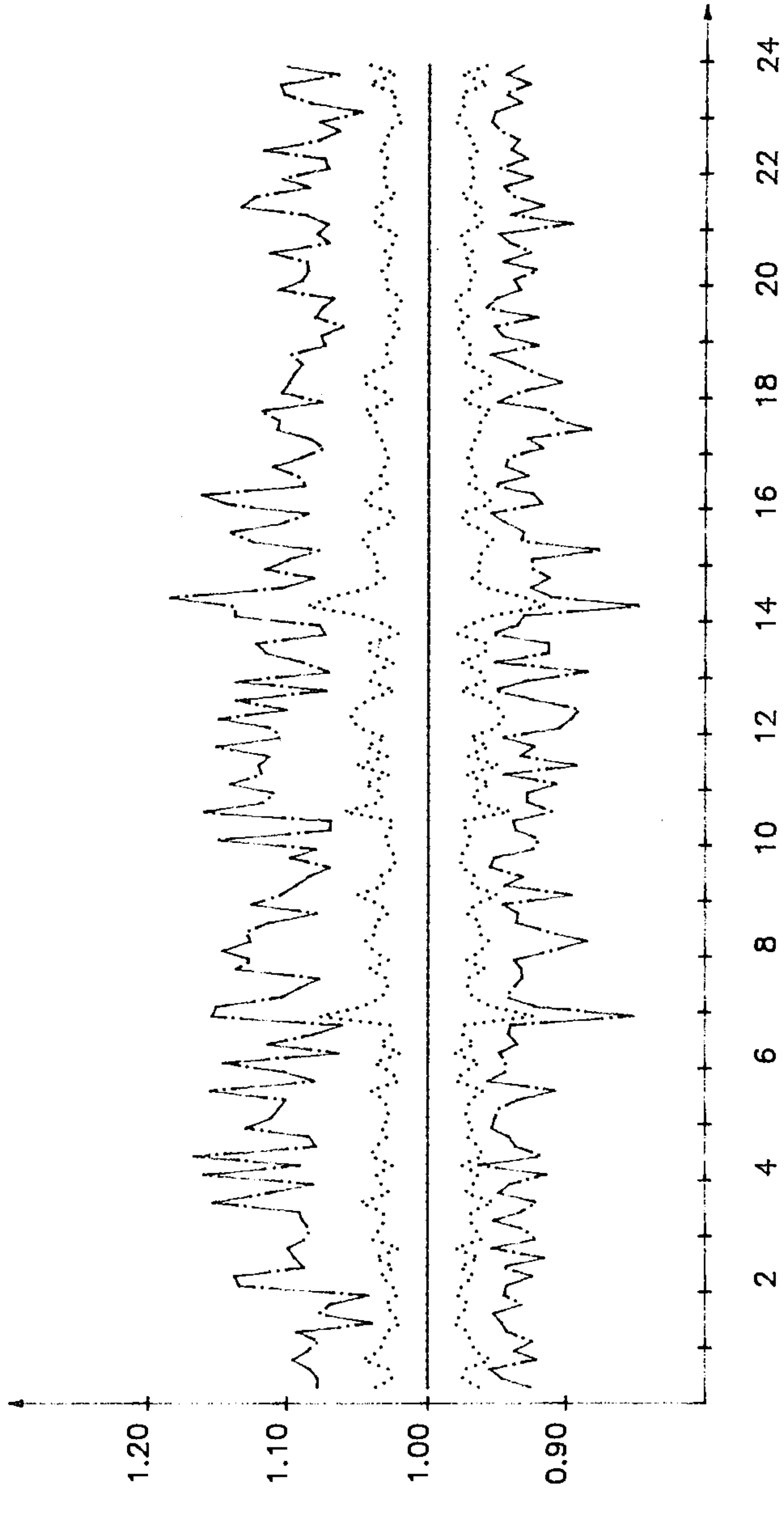


POWER DEMAND SUNDAY 31.03.85

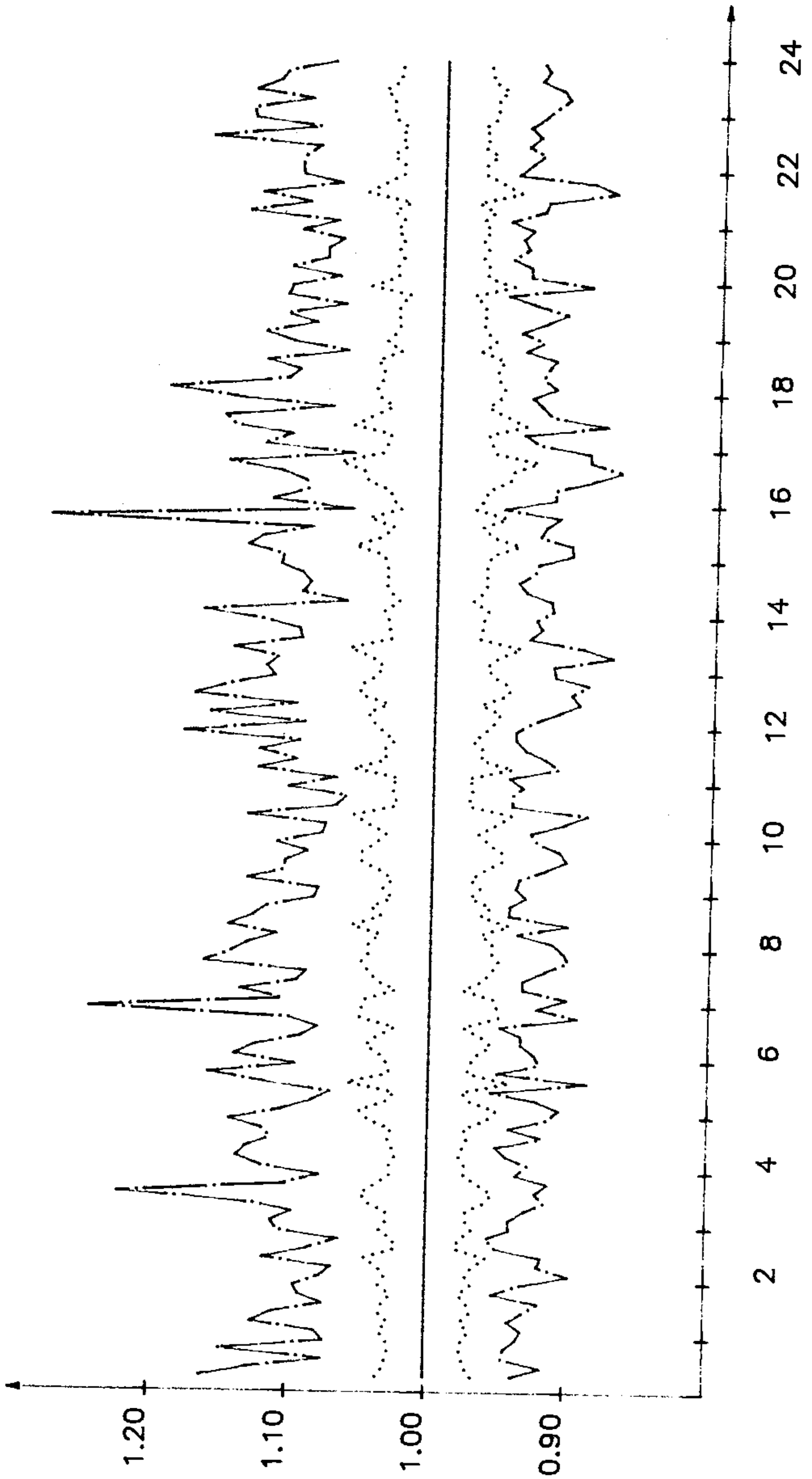



POWER DEMAND RELATIVE TO MEAN SUNDAY 17.03.85
1.20
1.10
1.00
0.90
2
4
6
8
10
12
14
16
18
20
22
24

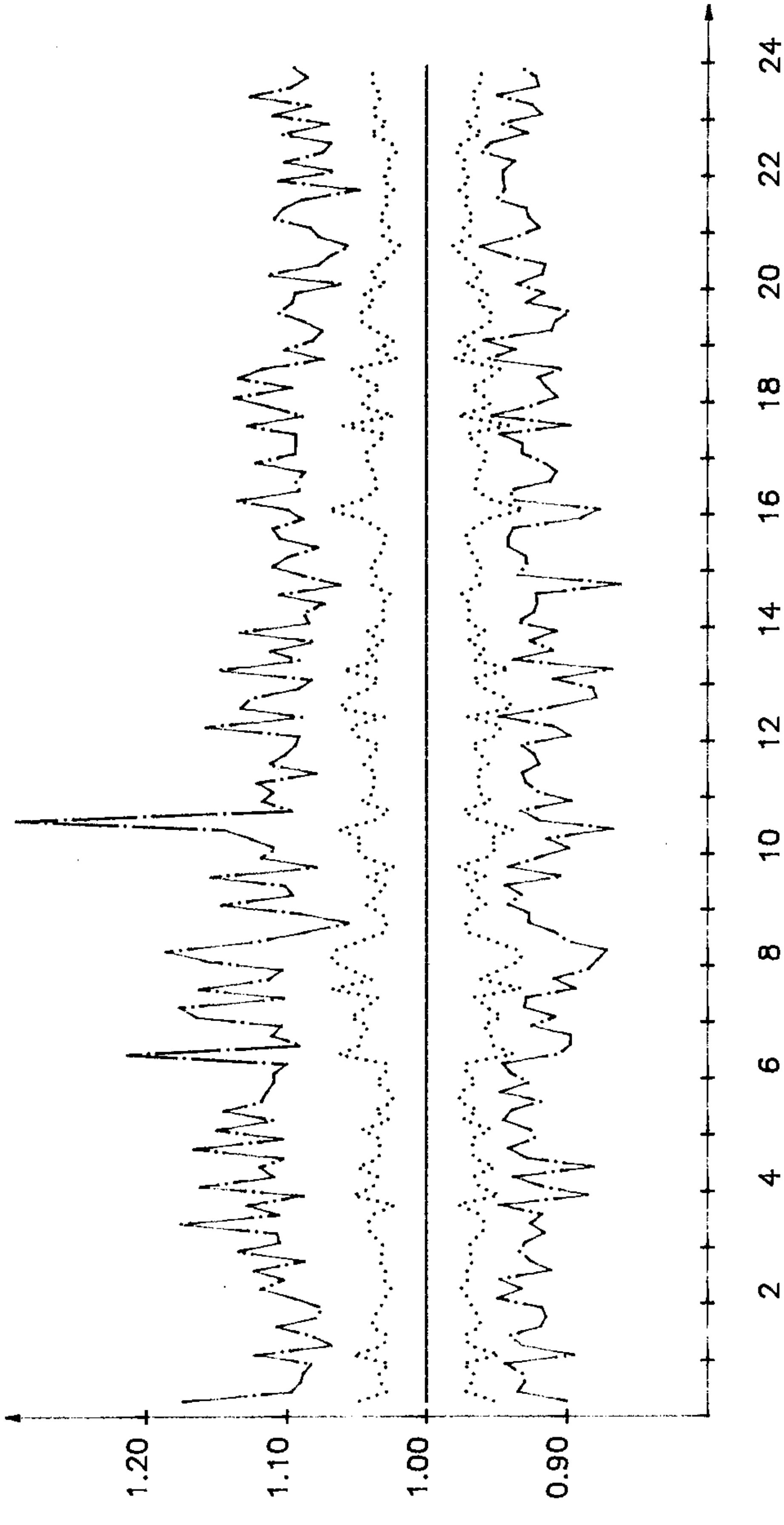
POWER DEMAND RELATIVE TO MEAN THURSDAY 21.03.85



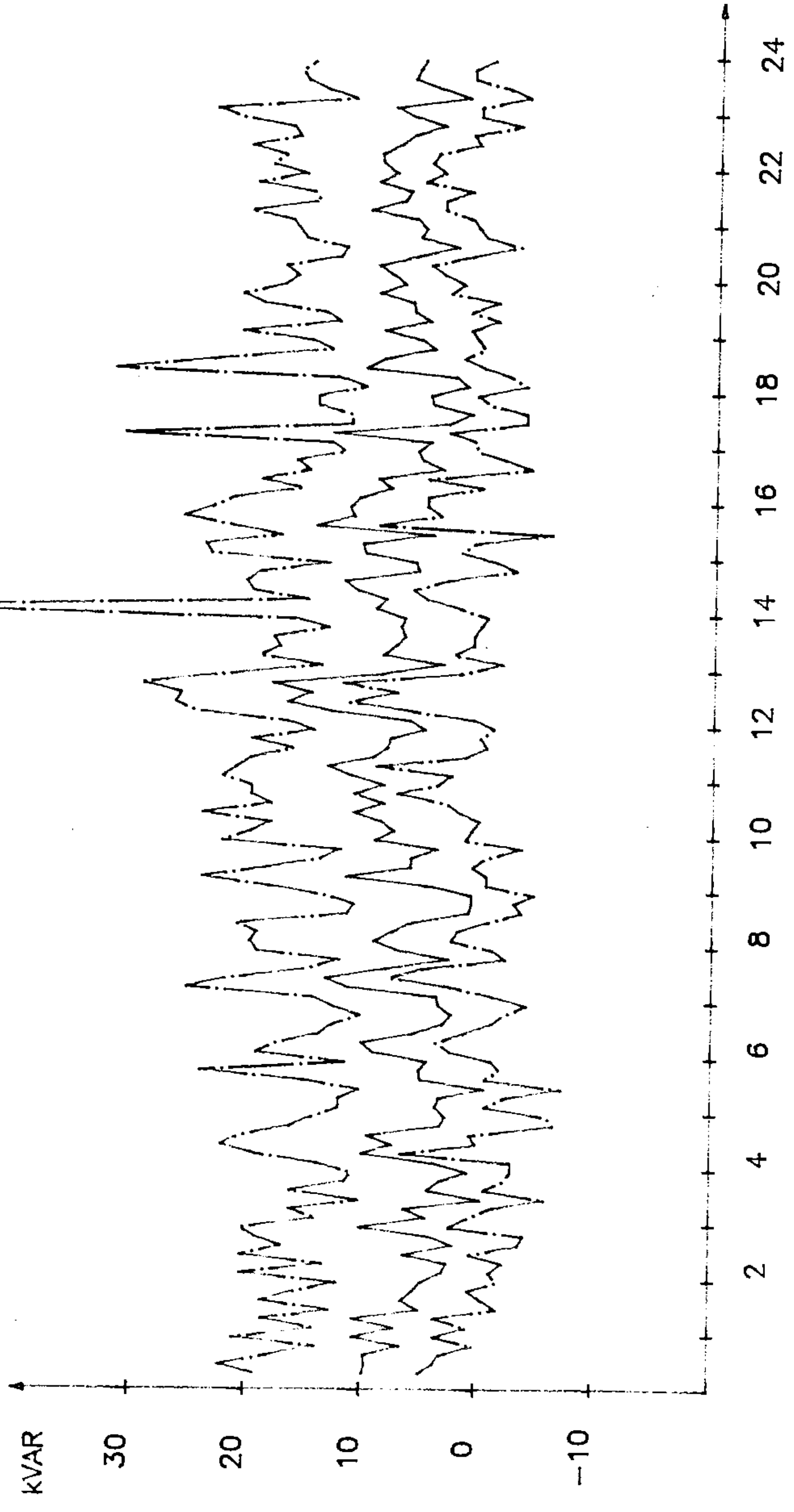
POWER DEMAND RELATIVE TO MEAN FRIDAY 22.03.85

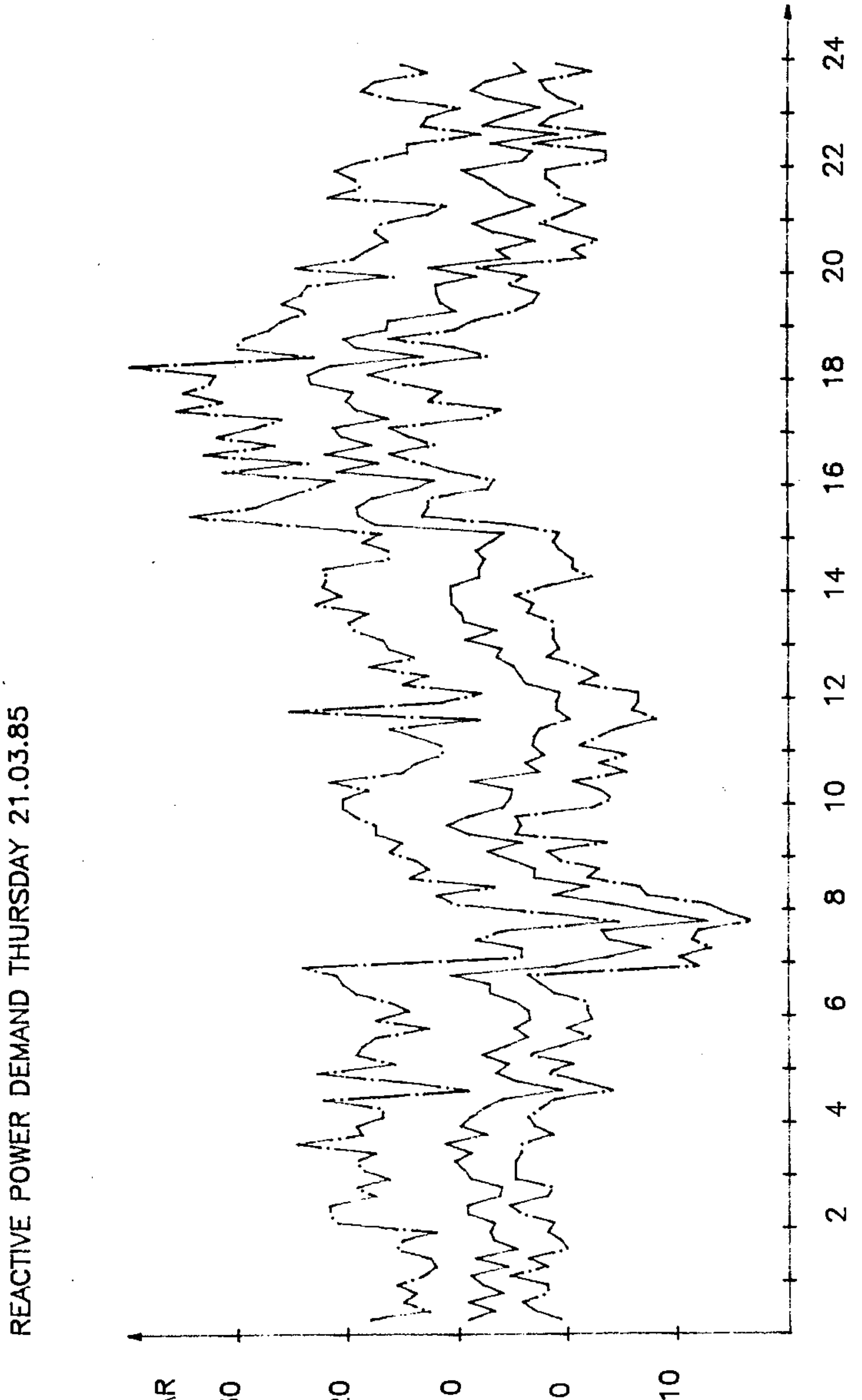


POWER DEMAND RELATIVE TO MEAN MONDAY 25.03.85



REACTIVE POWER DEMAND SUNDAY 17.03.85




REACTIVE POWER DEMAND THURSDAY 21.03.85
kVAR
30
20
10
0
-10
2
4
6
8
10
12
14
16
18
20
22
24

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Title and author(s)

Electricity demand patterns on Anholt
A small island without connection to the main power grid

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Date March 1988

Department or group Energy Systems Group

Groups own registration number(s)

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Pages 54 **Tables** **Illustrations** 44 **References** 10

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Abstract (Max. 2000 char.)

Abstract. This report contains the results from a study of the electricity demand made at the island of Anholt during 1984 and 1985. During 3 weeks in March 1985 measurements of power and reactive power demand was made with timesteps of 1 second. These data together with existing data for 1984 was analysed in order to examine the variations in the power demand, short time as well as long time variation, which are of great importance in the analysis and design of wind/diesel systems. The Island of Anholt is of special interest because it is without connection to the main Danish grid and because it has been considered to install a wind/diesel system here. The technical data and the operation of the existing power station at Anholt are described in appendix A. Appendix B contains a set of curves showing the daily variations in power demand.

Descriptors – EDB

ANNUAL VARIATIONS; DAILY VARIATIONS; DEMAND FACTORS; DENMARK; INTERCONNECTED POWER SYSTEMS; ISLANDS; POWER DEMAND; POWER GENERATION; WIND TURBINES